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COMET *e* 1894 AND THE LOST COMET OF DE VICO, 1844 I.

H. C. WILSON.

FOR POPULAR ASTRONOMY.

On the night of November 20 last a comet was discovered by Edward Swift, son of the well known astronomer Lewis Swift, who is now using his 16-inch telescope on the top of Echo Mountain near Los Angeles, Cal. It was a very faint comet, beyond the reach of small telescopes, and would have attracted little attention but for the fact that the computers of its orbit soon found it to be moving in a path very like that of the long lost comet of De Vico, known as 1844 I. As soon as this fact became known, observers who had the larger telescopes at their disposal attempted to secure as many observations as were possible. In December, however, the weather was generally bad and the comet was much fainter than when first seen, so that few observers succeeded in seeing it at all. Professor Howe, with his new 20-inch telescope at Denver, Col., obtained a good series of observations extending from Dec. 15 to 25, and at Northfield we were fortunate in catching the comet on seven nights from Dec. 14 to Dec. 31. These, with five observations in November by Barnard at Lick Observatory and a few single ones at other places, are all the observations as yet available. It is to be hoped that the little stranger will not escape without yielding once more, after the January Moon has past, to the light grasping power of some of the giant telescopes, for a few observations then will be decisive as to the character of its orbit.

Dr. L. Schulhof, at Paris, concluded at once, from his calculations based on observations in November, that the comet was identical with that of De Vico. The American computers have been less confident. Dr. S. C. Chandler after using all the available observations says (*Astronomical Journal* No. 333):

"This comet presents unusual difficulty in the attempt to determine the form of its orbit directly from the observations. Indeed the eccentricity is practically indeterminate, even a parabola sufficing to represent the whole observed path tolerably well. The following elements have been obtained by varying the ratio of the distances and the major axis; but the adopted value

of the latter is very uncertain. I have not thought it worth while to carry the approximation further until more observations are at hand. Unless these are obtained by the large telescopes, after the present Moon is out of the way, the comets theory must remain in a very imperfect condition."

The following are Mr. Chandler's elliptic elements:

$$
\begin{aligned}
T &= 1894, \text{ Oct. } 12.4365 \text{ Greenwich M. T.} \\
\omega &= 256^\circ\ 46'\ 50''.7 \\
\pi &= 345\ \ 32\ \ 48\ \ .1 \\
\Omega &= \ \ 48\ \ 45\ \ 57\ \ .4 \quad \Big\} \ 1894.0 \\
i &= \ \ \ 2\ \ 57\ \ 55\ \ .1 \\
q &= 1.39226 \\
e &= 0.56975
\end{aligned}
$$

Below we give for comparison the elements of De Vico's comet by Brünnow and those of Swift's comet by Schulhof, together with parabolic elements by Father G. M. Searle which closely represent the observed path of the comet.

	De Vico's Comet.	Swift's Comet.	
	Brünnow.	Schulhof.	Searle.
T	1844, Sept. 2.484	1894, Oct. 12.164	1894, Oct. 22.221
π	342° 30′ 48″	345° 20′ 4″	348° 55′ 54″
Ω	63 49 38	48 35 23	44 25 58
i	2 54 46	2 58 47	3 11 49
q	1.18632	1.39103	1.51948
e	0.61737	0.56891	

It will be seen that the elliptic elements of the two comets agree closely, differing most in the longitude of node (Ω) and the perihelion distance (q). In order that the reader may more readily get some idea of the relations of these orbits we have prepared the diagram in Plate XXII. It shows the orbit of De Vico's comet, the elliptic orbit calculated for Swift's comet by Dr. Chandler (that computed by Schulhof is almost identical with it), and a part of Searle's parabola; also the orbits of Earth and Mars and a part of that of Jupiter. The broken lines represent the portions of these orbits which lie below the plane of the ecliptic; the smooth lines all lie either in or above that plane. The line *NN* represents the line of nodes, or intersection of the plane of De Vico's comet orbit with that of the elliptic; $N_1\ N_1$ is the line of nodes for Chandler's orbit of Swift's comet and $C_2\ N_2$ is the corresponding line for the parabolic orbit. P, P_1 and P_2 are the perihelion points of the three orbits and A and A_1 the aphelia of the elliptic orbits; the aphelion of the parabola is at infinity. The inclination of the comet orbits to the ecliptic is only about 3°, so that the reader has only to imagine them to turn a little around their

respective lines of nodes in order to get their true relation to each other and to the planet orbits. The points A and A_1 would thus be elevated about one seventh of an inch above the plane of the paper.

The letters E_1, E_2 and E_3 mark the place of the Earth on the dates Nov. 20, Dec. 20 and Jan. 20. The capital letters C_1, C_2 and C_3 in like manner mark the place of the comet in the parabolic orbit and the small letters c_1, c_2 and c_3 its place in Chandler's ellipse on the same dates.

Which of the orbits is near the true one cannot be decided positively now, but it is probable that the ellipse is very nearly correct, and if this be true the probability that the comet is identical with that of De Vico is very large, in spite of the considerable difference in perihelion distance and line of nodes. If they are identical, that of De Vico must have been changed by some force outside of the Sun. That force we may find in the attraction of the planet Jupiter, provided the two were ever, during the last 50 years, in the region of the comet's aphelion at the same time. Assuming Brünnow's period of 5.46 years for the comet to be correct we find that it was at aphelion in the following years which we put side by side with the years when Jupiter was in the same longitude.

De Vico's Comet.	Jupiter.
1847.4	1850.0
1852.9	
1863 8	1861.9
1869.2	
1874.7	1873.7
1880.2	
1885.6	1885.6
1891.1	

Comparing these dates we see that there was no close approach until 1885, when, as will be readily seen by referring to the diagram, the coincidence was so close, that for two years the comet and Jupiter moved along together in roughly parallel paths, at such a distance apart that the influence of the planet must have been cousiderable. That influence would be exerted in just the right way to cause the change from the former path into that of Swift's comet. It would draw the comet outward into a larger orbit, it would cause the aphelion point to move around in the direction of Jupiter's motion and would draw the comet downward toward the plane of the ecliptic, thus causing the line of nodes to move backward.

The orbit of the new comet intersects that of the old one near

the point where the perturbations were greatest, which satisfies another criterion of identity. The changes in the elements are not greater than might be expected from the long continued perturbations. LeVerrier in his researches on the orbit of De Vico's comet, found the following sets of elements for that comet at the various epochs. The differences in several instances are greater than those between the elements of 1844 I and of Swift's comet.

Epoch.	π	$\vee$	i	φ	μ
	° ′	° ′	° ′	° ′	″
1753	315 37	306 45	2 9	33 58	604.9
1763	320 26	159 52	1 22	34 28	611.3
1775	324 47	145 2	4 49	34 47	614.3
1787	329 27	141 28	6 35	34 21	608.9
1799	334 24	135 18	5 56	34 38	606.2
1811	338 24	118 29	4 3	35 11	613.8
1844	342 31	63 50	2 55	38 7	649.9

It will be noticed on the diagram that the new orbit passes close to that of Mars. I do not find, however, that there has as yet been any near approach of the comet to that planet, but it is possible that at some future time there may be a disturbance from that source. It is more probable, however, that Jupiter will, in 1897, again change the comets path so that it will be beyond the reach of Mars' influence and possibly be lost again to Earth.

The unexpected discovery of a comet lost for 50 years, and found again at its ninth return, will, if the identity be fully established, be a very important fact. It will throw a good deal of light upon the physical condition of these mysterious bodies. showing that they change very much in appearance. The comet of 1844 was very bright, was indeed visible to the naked eye for some days. Its elements were well determined, yet it was not seen at subsequent returns, although searched for carefully. In 1853 it was as favorably situated as in 1844 but was not seen, except possibly on one occasion by Goldschmidt, who found a nebulous object not far from the calculated place of the comet, It may be that this is ordinarily a very faint comet, but that in 1844, from some cause, there was a temporary brightening like that which took place in the case of the Holmes comet of 1892 and to a less degree in several other comets. It may be the usual fate of the comets to fade away gradually, with temporary rallies in brightness, their final fate being total darkness. LeVerrier thought that the comet of DeVico was identical with the brilliant one of 1678. If so, it was lost to sight for many periods before it was seen in lessened splendor in 1844. Should it dimin-

ish again in the same proportion there is little hope of its ever being seen at another apparition.

This discovery will encourage computers to attack again the problems of other lost comets, like Brorsen's and Biela's. Should it be proved that during all these 50 years, this comet has been moving very nearly in the path which would have been calculated for it, had the computers persevered in their work, observers will have more confidence in the calculations for the other comets, and will make more careful, systematic and prolonged search for them. They will not feel obliged to search over so large an area of sky, and so can use powerful telescopes, so that possibly some traces of even Biela's or Brorsen's may be found.

NEARER TO THE STARS.*

PROFESSOR E. E. BARNARD.

In speaking with Alvan G. Clark (the sole survivor of the firm of Alvan Clark & Sons, and the discoverer of the companion of Sirius) in April of 1893 he expressed himself as ready, just as soon as the forty-inch was finished, to begin a five-foot object glass, and I rather inferred from his conversation that such was only waiting the completion of the forty-inch. He was then at work on the forty-inch discs, one of which lay on a bench covered with an old piece of sacking near a low window, which on the outside was level with the ground. A careless stone from a still more careless boy's hand could easily have dashed through the window and smashed the lens, but Clark didn't seem at all put out when this was mentioned as possible, and simply remarked that the object glass was insured for $60,000. Perhaps he had more confidence in the Cambridge small boy than I had. An accident to the glass now would doubtless delay the great telescope from three to four years.

What Americans cannot do in the way of great glasses by the Clarks and by Brashear, and what mechanical difficulties they cannot overcome in mounting these great glasses through the genius of Warner and Swasey, is certainly not worth while undertaking elsewhere.

It is possible, however, that our great telescopes of the future—I speak now in point of actual size—will be some form of the reflector, such for instance as the one projected by the French for

* Chronicle, San Francisco.

their exposition of 1900, and that which Sir Howard Grubb has but recently proposed.

The question now arises: Is there any limit to telescopic power, or can we continue to make and use bigger and bigger telescopes yet? To most intelligent people this question will at once resolve itself into two parts. First, will it be possible to make very much greater lenses? This question our native opticians will answer for up to six or seven feet. Second, can the mechanical difficulties encountered in mounting these great telescopes of the future be overcome? When we have made a perfect object glass six or eight feet in diameter, can we mount it in a slender steel tube 100 feet or more in length so rigidly that when it is turned to any point of the heavens there shall be no strain upon it sufficiently great to destroy the perfection of the image, and which shall move by the most delicate mechanism and follow uniformily the motion of a star?

This question was even a consideration in building the Lick thirty-six-inch, but Warner and Swasey satisfactorily answered it. That they have done the same for the forty-inch no one will question. But there must be a limit even to their skill. Just where that limit may be I shall not attempt to say, for there is something else still more potent to deal with in our future great telescopes, and over which man has absolutely no control.

The atmosphere itself, which is so necessary for our very existence, is the greatest foe to the future great telescopes, just as it is already to these of to-day.

The ideal place for a great telescope would be that one which had no atmosphere at all. But such cannot be found on our planet, and if it could a new kind of observer would have to be invented to run the telescope. Therefore we must be content to work with our atmosphere just as it is.

It is not the clouds that float in our atmosphere and which intercept our view that we have most to dread, though of course if continuous these alone would be sufficient cause for complaint. The real trouble oftenest occurs when the air is very clear. (The clear, crisp wintry night, when the stars are bright and sparkling, is the worst possible time for a telescope, for on such a night the images are a mass of boiling and quivering light). We are at the bottom of a great ocean of atmosphere that covers the entire globe. To see the stars and the other heavenly bodies we must look at them through this vast ocean of air. If this aerial ocean would keep perfectly quiet while we looked it would be all right. But unfortunately that is its last intention. Sometimes it is fairly

quiet, but in general it is very unsteady. Often it is in a fearful commotion. The result of this disturbed condition of the air is to more or less totally destroy the image of a celestial body when looked at in a great telescope.

As I have said, there are nights when the air is almost perfectly quiet. If under this condition we look at a star through a powerful telescope it glows with a steady and beautiful radiance. On such a night everything that is at all within the reach of that telescope can be seen with it. The finest and most delicate details upon the surface of a planet, the faintest star or satellite, all come out with a distinctness that permits the most delicate and accurate observations to be made. If this condition always existed, the work of an observer would be exceedingly pleasant and profitable, but such seldom occurs, and its occurrence is rarer the bigger the telescope, and when it does occur it does not last for any great length of time; a couple of hours of such perfect seeing and then the air becomes disturbed and the image more or less tremulous and blurred. The delicate details are lost and the faint satellite is blotted from view. If the observer has the run of several different sized telescopes he will appreciate this peculiarity of the atmosphere.

There will be nights on which he can successfully use a 6-inch glass that will not permit a satisfactory use of a 12-inch, and which would wholly forbid the use of a 36-inch. In this case the tremors present in the air would not be sufficiently magnified by the 6-inch to affect the clearness of the image. But with the 12-inch (four times as powerful) these tremors would be so magnified by the greater power of that glass as to spoil the clearness and definition of the image. The yet greater power of the 36-inch (thirty-six times as powerful as the six-inch) under these conditions will so increase the effect of this disturbance as to totally destroy the image. Such nights have occurred where features could be seen in the 12-inch that were entirely blotted out in the 36-inch. But let the conditions be the best for observing with the air steady, and the 36-inch is far ahead of the 12-inch. It is very seldom, however, that the tremulousness of the air is not more or less apparent in the 36-inch, and under such conditions it is difficult or impossible to use the highest powers of the telescope. One has to wait and watch patiently and snatch a moment here and there of steadiness to do his best work. Now let us increase our aperture to, say, forty inches. The atmospheric conditions being the same, then this quivering of the air, which has been objectionable in the 36-inch will, through the greater

power of the 40-inch, have become far more objectionable. Now let the two instruments remain under the same conditions, but let the air grow more tremulous. We shall notice the effect soonest on the 40-inch, and after it has become unbearable in that telescope it will still be tolerable in the 36-inch, and, much later, in the 12-inch. Now, let us imagine another telescope still more powerful, say several times as powerful as the 40-inch. The effect of a slight disturbance in the air is multiplied just as many times more, and we should have to look long and often during a year to find a night that would permit only a few hours of good observing with that great telescope. In general, it would be so crippled by the unsteadiness of the air that its effective power would much of the time dwindle down to that of the 40-inch, or even below it. But, when a few hours of the best seeing did come what marvels that glass would show!

Let us go now still a little further and make our telescope still more powerful. We rapidly diminish the number of hours in the year that the atmosphere would permit its use at all. Still, let us increase the size and power of our telescope—for we may suppose our American ingenuity unlimited—and we shall never find an hour during which our instrument can be used to perfection, because the slight tremors ever present in our air would forever baffle the use of such a telescope.

So, looking at the matter in this light, we can see how, though the optical and mechanical difficulties may be overcome, the atmosphere itself is going to limit the practical use of great telescopes in the future, and in the end, if successfully made large enough, will prohibit their use at all, or at least make them inferior to smaller telescopes.

However, though I am confident the working hours of the future great telescope will be much diminished, yet I believe much bigger telescopes will be made and successfully used, but in the end the atmosphere will limit the effective work before the optician and the mechanician give up.

Of course, it is unnecessary to say that a favorable site upon the Earth's surface for a great telescope will aid much in making its powers effective.

As for the telescope proposed by a Chicago man—a arge lens made up of many smaller ones, like the eye of a fly—it is safe to say that no great telescope will ever be built on that plan, and if it should be (and we don't know what people may do nowadays), it will be absolutely safe to say that it will never be successfully used.

THE STUDY OF PHYSICAL ASTRONOMY—SUGGESTIONS TO STUDENTS AND AMATEURS.

T. J. J. SEE.

FOR POPULAR ASTRONOMY.

The editor of POPULAR ASTRONOMY has requested the writer to contribute something of interest to students and amateurs, and especially to point out some of the more difficult lines of astronomical research in which a beginner may reasonably aspire to work. As astronomy is by its nature an exact or mathematical science, some persons shrink from it in the belief that only the especially gifted can expect to achieve successful results. This common mistake has doubtless deterred many from accomplishing what was really within their power, if only they had been endowed with a sufficient faith in their own abilities, and the degree of perseverance which characterizes successful enterprises in other lines of human activity.

We might strengthen this proposition by the testimony of some of the most distinguished men who have ever labored in the cause of science, and could show that those who have made the greatest discoveries have claimed that they did so mainly by great industry and ceaseless perseverance.

Thus, it is related of Newton that when a friend asked him how he made his great discoveries, he replied, "Simply by constantly thinking about them;" the great philosopher being too modest to claim for himself anything more than the usual ability. Fourier in his eulogy on Laplace says: "His constancy has triumphed over all obstacles * * * he has devoted his life to astronomy with a degree of perseverance of which the history of the sciences is perhaps without another example * * * he would have completed the science of the skies if it had been possible * * * he has composed the Almagest of the 18th Century." And one of the most illustrious of American astronomers recently said to the writer, in explanation of how his vast and splendid work had been accomplished at so early an age: "Well, I have been very industrious."

These modest claims for great men must not be construed to mean that great ability is not required for great discoveries, but that the ability of most persons, if fully developed, is much greater than is generally supposed.

What line of work then should a student in astronomy choose? Should he turn his attention to an easy subject and follow the

rapid road to temporary success, or should he take a view which is more serious and more worthy of his exalted science, and plan for a profound study of the great law of gravitation and the mechanics of the heavens, which can alone make known the past and future states of the planetary system, at ages so remote that man has never witnessed and perhaps never can hope to witness the events predicted? Should he not desire to know something of the unfailing law of Newton by which we trace the planets through the ages and know with certainty what will be the celestial phenomena in distant centuries, even if the appearances can never be observed?

The majority of students are generally encouraged to take up some easy task, and accordingly of late years the subject of photography has been a great temptation to the student, the amateur, and to a large number of astronomers. It is hardly necessary to add that while amateur photography is a harmless amusement, it is not likely to lead to important scientific results. By this it is not meant to say that the wonderful development of photography is not worthy of study, and it is admitted that judicious applications of the camera for gathering facts of observation are of the highest importance; but it is maintained that the photograph can at best give only facts, and the explanation of the facts must always be sought in the fundamental laws of force and motion. Therefore the great powers of the photographic camera are only a means, and not an end; and to believe that photography can reveal other than facts of observation is to err seriously regarding the process of real scientific discovery. When the plates have recorded the appearance of the heavenly bodies, the material is at hand for a mathematical discussion of the results, which alone will be adequate to disclose the real laws and causes of the phenomena recorded. There is of course an artistic side to the question, and it might be maintained that photographs are inherently beautiful and therefore desirable; but if we regard the camera from the scientific point of view only, it can not be denied that photography is only a means to the ends of science, which has for its object the explanation by known principles of the phenomena presented by the material universe. An amateur may ask: But has not astronomical photography, from some cause, made the impression upon the public mind that it is at once the object and the end of astronomical aspirations? If this is so, history will record it as one of the eggregious errors of this age. For when we look at the matter in its true light we see that photography is simply a fine and very exact means of

gathering facts, and that its delicacy is such that sometimes facts are discovered which are beyond the direct vision of the astronomer; and therefore photography has rendered great, and is capable of rendering still greater, services to the progress of observational astronomy.

In like manner, when the spectral lines of the stars have been recorded by the sensitive spectrograph, we have the material for an examination of the constitution of the fixed stars and their motions towards and from the Earth. But we gain no real insight into the working of the universe without subjecting our material to a critical analysis. Therefore although much excellent work has been accomplished in spectroscopy, and probable physical explanations of the phenomena revealed by the spectra of the fixed stars and nebulæ have been devised, our real knowledge of these phenomena is, we fear, not so great as is generally supposed. It is a somewhat discouraging circumstance that we find the spectrum of the same substance under different conditions is not infrequently entirely different, so that if we are ignorant of the conditions existing in space, we must remain somewhat doubtful as to the correct interpretation of the spectral phenomena of the heavenly bodies. Although the wave-lengths of the principal nebular lines have been very carefully measured, and some of the nebulæ are found to be moving in the line of sight with velocities which can be determined with a high degree of precision, we appear to be still in the dark as to the elements which give rise to the lines in question. The outlook is not improved by the fact that we are almost completely ignorant of the physical conditions existing in space, such as the temperature, the pressure and the density of the nebulæ. Mathematical research might throw some light upon the constitution of these diffused masses, but without such analysis, observational astronomy will probably be powerless to effect any discovery of the laws of force and the properties of matter which prevail in those remote regions of the universe.

It is true then that photography and spectroscopy supply chiefly the material for astronomical work, and that no progress in physical astronomy can be made without applying a rigorous analysis to the results of observation. Therefore we see that progress in physical astronomy—the astronomy which explains phenomena by their true mechanical causes—must be effected in our time by the same principles which guided Newton and Laplace, Adams and Leverrier. And it is not easy to see the scientific propriety or justice of names such as the "New Astronomy;" since while the so-called "New Astronomy" is occupied chiefly

with gathering observational data, the explanation of these facts must be sought in the principles of the "Old Astronomy." And the two branches of modern astronomy must necessarily remain forever united if true physical science shall continue to exist. The history of the ages shows that the one essential condition of true scientific progress is the constant treatment of observational material by mathematical theory; and when real physical laws have been thus discovered, they constitute the foundations of the great future developments of astronomical science.

As an example of this progress, we may take the familiar case of the law of gravitation. The arcients observed the motions of the heavenly bodies with hardly less zeal than the moderns, but being ignorant of the physical laws of the celestial motions (knowing at best only the *formal* laws, the eccentrics, epicycles, etc.) the observed irregularities in these motions were utterly bewildering. In modern times, however, when Copernicus had established the true system of the world, and Kepler had discovered the laws of planetary motion, and Newton had discovered and applied the law of gravitation as a true physical cause, it was seen that the irregularities observed by the ancients (such as the regression of the Moon's nodes, motion of the lunar perigee, the evection, precession of the equinoxes, etc.) are a necessary consequence of this great law of nature. The successors of Newton have been continually occupied with the development of the theory of gravity as applied in our system, but it is only since the time of Laplace that the law of gravitation has been used as a means of discovery as real as observation itself. Laplace and his successors during the present century have found that not only all the regular motions of the planets and the Moon, but also all the (important) irregular motions follow from the law of gravitation, and constitute the strongest proof of its exactness, so that this law is now the basis of all exact work in physical astronomy.

It will be evident, on general principles, that good astronomical work in any line is always valuable and important; but we may point out that the astronomy of the United States can truly flourish only when all lines are developed, and especially the exact or mathematical branches on which the whole structure rests. While at present the scientific method is fully developed only in physical astronomy and practical astronomy, the other more recently developed branches of the science also will doubtless eventually be reduced to a mathematical basis. These remarks are not, however, to be construed as indicating that physical astronomy has been exhausted by the researches of the great mathematical

astronomers of the last hundred years. On the contrary only a good beginning has been made, and the demand is constantly arising for more exact determinations of the perturbations of the heavenly bodies, and new applications and developments of the theory of gravitation.

Orbits must be found for new comets and new asteroids and new satellites and new double stars, and this work is as important now as it was in the time of Laplace, Bessel and Gauss. The time will never come when such work will cease to have a high value, since it is only by the finer determinations extended over long ages and to a variety of bodies that will enable us to detect the existence of any foreign cause, such as a resisting medium, working on the motions of the planets. It is only by such researches of the great astronomers of the past generation that we are enabled to say that the law of gravitation is exact to the highest degree, and that if any foreign causes are disturbing the motions of the planets, they must be very slight, and are hitherto insensible.

Some of our best universities now give encouragement to the profound study of astronomy, and hence the American student of average ability has an opportunity to enter upon these higher branches of the science, and has before him a boundless field of exploration.

Judging by the past history of exact science, is it not safe to predict that when the public sees more clearly the well-known limitations to photography, which astronomers recognize as a means of gathering facts for astronomical theories, the great historic subject of physical astronomy will again take the place assigned to it by Newton and Laplace, Gauss and Hansen, Gyldèn and Tisserand? For since physical astronomy is at the basis of astronomical science, as long as exact science shall exist the subject of gravitation in its manifold workings must continue to engage the attention of astronomers.

It may not be out of place here to point out an error which pervades nearly all popular astronomical literature. It is commonly supposed that the discovery of Neptune from the perturbations of Uranus by Adams and Leverrier is the greatest achievement of modern astronomy; but this is far from being the case. Other discoveries have required greater originality and have been more important from the scientific point of view than even the discovery of Neptune. Laplace's discoveries of the causes of the long-inequality in the mean motion of Jupiter and Saturn, and of the secular acceleration of the Moon's mean motion, are both

equal if not superior to Leverrier's work; and many other less conspicuous discoveries are from a scientific point of view of equally great importance.

Darwin's researches on the formation of the Moon lead, in the opinion of competent critics, to far greater discoveries than that of Neptune; since if Neptune had not been found in this century it must have been detected at some later age by its perturbations on the motions of Uranus, which would have been periodic; while the cosmogonic history of the Moon, could never be inferred from any observed phenomena either in our own or in any future age.

It is only too evident that the popularity of a discovery is a very poor criterion for its scientific value. A new planet, a new asteroid, a new comet appeals far more powerfully to the public imagination than the profoundest discovery in mathematical astronomy ever made by Newton, Laplace or Hill. But will anyone compare the two classes of discoveries? The illustrious example which has been set in this country by such astronomers as Bowditch and Peirce, Gould and Chandler, Newcomb and Hill ought to be of service in the advancement of American astronomy. Yet it is undeniable that for some cause the study of physical astronomy has been much neglected of recent years.

Dr. Gould, in offering the *Astronomical Journal Prizes*, recently said:

"There is perhaps no lack, in this country, of observers of comets, but it is unfortunately true that many of the observations have much less value than they would have if they were made more carefully and at judiciously chosen times. There is a notable lack, in this country, of mathematical investigators in astronomical lines. The great bulk of the work of definitive determination of orbits of comets and planets has been done in Germany and France. Two or three names only keep up our reputation in connection with the theories of the Moon and Earth."

The outlook for the future appears rather more hopeful, but it is evident that if the conditions of American astronomy are to be improved, those astronomers charged with the administration of prominent observatories and the professors of astronomy in our universities and colleges must make a more serious effort to educate astronomers.

By perseverance it is possible for an amateur to become a first-class observer (and great indeed is the honor which the writer would give to those astronomers who began as amateurs and who have rendered and are now rendering illustrious service to

the cause of American science). But the amateur of the present day can also find facilities for the profound study of physical astronomy, and by steadfast effort will be enabled to render a higher and greater service to the science of his country. The serious student might therefore with advantage think of working on orbits, and perturbations and attractions; and by the aid of such treatises as Klinkerfues's *Theoretische Astronomie*, Watson's *Theoretical Astronomy*, Gauss' *Theoria Motus*, Oppolzer's *Bahnbestimmung*, Newton's *Principia*, Laplace's *Mécanique Céleste* and Tisserand's *Mécanique Céleste*, he will be led into the most wonderful and the most interesting branch of astronomical science. The difficulty ordinarily encountered by a student is the mathematical one, but the writer believes that this is more easily overcome than is generally supposed. The suggestions embodied in this paper have been made with a view of pointing out certain lines in which a great service may be rendered to the future of American astronomy by those who are willing to spend time and energy in the sacred cause of science.

One thing can not be emphasized too strongly, viz.: That the interests of American Science demand that a greater number of students should devote themselves to physical astronomy, or celestial mechanics. Otherwise, where will be the Bowditches and Peirces, the Gouldis and Chandlers, the Newcombs and Hills of the next generation?

THE UNIVERSITY OF CHICAGO, 1895, Jan. 7th.

MARS.

PERCIVAL LOWELL.

THE CANALS. I.

FOR POPULAR ASTRONOMY.

In the autumn of 1877 the well-known Italian astronomer, Schiaparelli, while engaged in micrometric measurements of the markings on the planet, made a strange discovery connected with them; so strange that his announcement of it was at once received with disbelief. He found that the bright areas of the planet's surface were traversed by narrow dark lines linking the bluish-green portions of the disc to one another in a most singular manner. As the bluish-green regions were at that time regarded as bodies of water, he called the lines canali or channels, which was translated canals and became the now famous canals of Mars.

Such a system of aquatic communication—a Venice on a world-wide scale—was something without counterpart either in the Earth beneath or in the heavens above; and as it failed to fit either terrestrial or celestial experiences, it was with one consent refused recognition.

The general scepticism was furthered by the fact that no one but their discoverer could see these strange discoveries of his. Not only did no one else perceive them independently in 1877, but even after others knew what to look for and tried to make out the phenomena not a man of them succeeded in doing so. Markings which can now be shown to have been badly seen views of the canals were, it is interesting to note, observed by Schroeter at the very beginning of this century and by several observers since. But what is very good evidence after the fact is no evidence at all before it. These previous adumbrations of the canals were not then regarded as having anything to do with the case and carried therefore no conviction. To the same inconclusive category belong the long streaks seen and drawn by Burton and Dreyer in 1879.

So scepticism continued, while Mars came and went. Opposition succeeded opposition, each adding to Schiaparelli's discoveries on the one hand and to distrust of them on the other. For nine years this state of incredulity lasted; and not a scrap of confirmation did his discoveries call forth except from himself —which rather invalidated them than otherwise. Discredit was simply heaped on discredit; such being the world's way of appreciating a man who is ahead of his times. To be previous is to be pooh-poohed.

Meanwhile, the longer scepticism lasted the more was it laying up for itself against the day of its recantation. For Schiaparilli went from surprise to surprise. His first drawings in 1877 were not, as it seems to us now, so very startling. In 1879, however, his delineations became much more so, and in 1881 he announced that some of the canals had geminated; that is, that in place of a single canal there were now two parallel ones, running side by side often for more than a thousand miles. Such a Martian parody on railroad tracks, as it were, capped the climax to the general distrust. No one else, it will be remembered, had yet succeeded in seeing single in the matter.

How long the rest of the world would have remained in nescience of the canals had it been left to its own devices, will never be known; for the earliest confirmation Schiaparelli received was at the hands of such of his scientific friends as had

been spurred by him to the attempt. The first to succeed was Perrotin at Nice in April, 1886, after as nearly missing it as it was possible to come.

The occasion of his attempt was the completion of the great Nice refractor of 29 inches aperture. The great Washington refractor of 26 inches had already failed to show them, whereas Schiaparelli had discovered them with 8⅓ inches. An instructive comment this on the popular superstition about the superiority of large instruments; a superiority in reality quite secondary in matters of planetary detail to both observer and atmosphere.

Perrotin had, he tells us, made a first series of attempts to see the canals which was not encouraging and after a few days of fruitless endeavor, explained partly by the bad seeing, partly by the difficulty inherent in this class of investigations, had given the search up, then resumed it and was about to abandon it for good, when on the 15th of April he managed to make out one of the canals between the Syrtis Major and the Sabæus Sinus, the Phison. Mr. Thollon saw it immediately afterward. We can conceive the thrill that must have gone through those observers at the sight. For here was something which only one man had ever seen before, and which the world had denied to exist for nine years. The verifiers knew moreover the interest that would follow their announcement of the sight. For it is not the discoverer usually whom the world believes but the man who first sees the sight second.

In this case, however, in spite of their confirmation many astronomers still refused to be convinced and much discussion was indulged in as to the cause of the self-deception on the part of the alleged observers. All of which reads inapropos enough now. For time has brought ample testimony to the keenness and accuracy of Schiaparelli's discovery. Since 1886 each opposition has added new names to the list of those who have seen the canals with their own eyes. So that though sceptics still exist they form now the antiquated minority.

The reader will doubtless wonder how such a state of things was possible, that the many should all turn out wrong and the one right. Primarily, of course, this was the due to Schiaparelli's extraordinary keenness of vision, but it was supplemented by a certain as uncommon keenness of brain. Schiaparelli possessed the very rare faculty of perceiving what he saw. With him the eye worked the sensorium of its own accord. Commonly the brain has to be warned beforehand. Most people see only what they are prepared to see; as is well instanced in astronomy by

those observers who manage to mark with surprisingly small instruments what others have already discovered, and yet who make no discoveries of their own.

But there is a second fact ancilliary to the first. The essentials to good observation are not understood to the perfection that they ought to be. I may mention here one or two very simple points out of many.

Reflectors should be shunned; alluring though they be. Reflectors possess certain great advantages over refractors and certain corresponding great disadvantages.

They are cheap; they are easily handled; and they can be made of great size; all of which commends them to the unreflecting. They can be made so big in fact that as light gatherers they are unrivalled; but as definers they are also unrivalled—unfortunately in another direction. The distortion they produce is about three times as great as is the case with refractors. The result is that for planetary detail they are well-nigh worthless. This shows itself very lamentably in portraits of the planets. Anyone who will compare the drawings of Mars made by reflectors with those made by refractors will mark the sad incompetence of the mirror. In those rare instances where much has been seen by a reflector it has been seen by the observer in spite of his instrument, not in consequence of it.

In the next place atmosphere is all important.—An atmosphere which is good enough for observations on the stars is not good enough for fine detail on the planets. Lastly the observer must have the capacity for taking infinite pains or as near it as his finite incapacity will allow. Patient watching for the best moments is the "open sesame" to the unseen.

Time has not only justified Schiaparelli; it has shown the canals to be even more enigmatical than his first description of them. Indeed the better they are seen the stranger they look; these Martian peculiarities that have had so hard a time in getting themselves recognized. We will now see how they look. Unfortunately the drawings intended for this article will have to appear later, so that a description alone must do double duty.

Over the whole of the bright continential areas of Mars extends a network of fine lines that cross one another in every possible direction. Each line starts from some well-marked spot on what for the moment we will call the coast, and pursues a strangely definite course, swerving neither to the right hand nor to the left to another equally well-marked spot upon the opposite coast, or else to a point of rendezvous of several canals in the middle of the continent.

As a rule each line is a straight line; that is it is part of a great circle and therefore the shortest distance between the two points which it connects. The chief exceptions are a few of the very short canals which are curved, but even their curvature is of a perfectly definite kind like that of any geometric curve. In viewing drawings of them, however, it must be remembered that unless a canal or its prolongation pass through the centre of the disk, the curvature of the sphere must make it appear curved, though in reality it be perfectly straight.

Secondly, each canal maintains approximately the same width throughout its length. This is very accurately evidenced by the fact that after the canal has once developed it is seen, unless too far round the disk, either in its entirety or not at all, according to the seeing. It is very rarely seen in part. As some canals are on the limit of visibility owing to their narrowness as it is, this is a very fine criterion of their sameness in size throughout.

The canals all radiate from certain centres, the bays above mentioned or the rendezvous spots I have spoken of. Many canals meet at each of these centres, which are thus either points of departure or junction termini. If one were to begin by laying down these points and then connect them by great circles so as to go with the greatest expedition from one centre to another, he would have a very good idea of what the system looks like.

Such a plan would not only represent the canals already known but apparently enable anyone who started with the junctions as a base of operations to foresee canals for the future. For example there appears on Schiaparelli's map a large space quite destitute of canals, the largest vacant territory on the planet in fact, lying between the Gigas, the Eumenides, the Titan and the Pyriphlegethon. Adjoining it are two other vacant spots of no mean size, one to the south-west, the other to the north-east of it. It is a region that commends it to the imagination for many romantic purposes, as a mass of wild high country for example or a great desert for explorers to be lost in. Unfortunately the general scheme is a better prophet than romance. For there turns out to be a very long and important canal that runs straight through the centre of the supposed vacant space, the Brontes, which starts from the Sinus Titanum and runs down the disk more than two-thousand miles, apparently to where the Acheron and Phlegethon meet.

Another instance of falling most obligingly into its preconcieved place, is the Ulysses, a canal that joins directly the beak of the Sirens with Ceraunius. Still another is the Medusa, running

from the mouth of the Gorgon to where the Sirenius crosses the Eumenides. And so we might multiply instances of the essentially systematic character of this most suggestive network of lines.

Such fairly startling accomodation of means to ends is further borne out by the form of the canals themselves. For each is singularly narrow in proportion to its length. Not uncommonly a canal will be as much as two thousand miles long while one is rarely ever fifty miles broad. And though the canals differ between themselves somewhat in width and very much in length, there are none so far discovered whose length does not very much exceed their breadth. Of the canals proper—for there are some which in whole or part partake of the nature of estuaries, such as the Nilosyrtis and the Hiddekel—the width varies from the limit of visibility, which may be taken at abont half a Martian degree or 18 miles, up to about 2 degrees or 75 miles—not a very great difference considering the enormous difference in length.

Some of the canals are excessively long—the Gigas-Uranius is about four thousand five hundred miles in length from one end to the other. Indeed by some trifling accomodation at the junctions it is possible in one instance to keep practically one straight course completely round the planet in a spiral for a distance of about nine thousand miles. One has only to begin at the Margaritifer Sinus and follow along first the Hydraotes, then the Nilus, the Phlegethon, the Gyndes, the Heliconius and the Callirrhœ to the Mare Acidalium, and he will find himself due north of the Margaritifer Sinus from which he started.

On the other hand the Nectar and the Ganymede (the little link between the Agathodæmon and the Lake of the Sun) are but 250 miles long or less.

Now one characteristic of the canals is as important as it is striking.

At certain times the canals are invisible; and their visibility or invisibility has nothing whatever to do with our atmosphere or with that of Mars. It is a characteristic inherent in the canals themselves. Furthermore it follows dutifully upon the Martian seasons. In the late winter or early spring of the southern hemisphere the canals are invisible with the telescopic power we now possess. As the spring advances they begin to show as very fine lines that with bad seeing masquerade as broad, faint streaks. From this time on they gradually darken and broaden somewhat till they have attained their maximum width of about fifty miles or less after which the process is reversed and they disappear again. In short the canals grow.

During their evolution they are rather more conspicuous at their debouching ends, rather as if they were a trifle larger at those points than as if development began there. But this difference is almost imperceptible. The striking thing is that practically they develop simultaneously throughout their whole length if this does not exceed a thousand miles.

They do not all begin to develop at the same season. Those nearest the south pole start first. The Solus Lacus region is the one to lead off the list. Then the others follow in their order north. Proximity to the dark regions, however, seems to further the process and those near such areas begin before the time their latitude strictly would warrant. Such is the case with the canals about the Sabæus Sinus and still more markedly with the Ganges.

Development does not immediately follow the transference of the polar water north. Some weeks elapse after the water has to all appearance gone down the disk before the canals appear; a delay of just about the length of time it would take vegetation to sprout. What this hints as to the probable character of the canals we shall see in the next paper when we come to take up some still more recently discovered phenomena intimately connected with the canals—the oases.

LOWELL OBSERVATORY, December, 1894.

THE ASTROLABE.*

MARGARET L. HUGGINS, LONDON, ENGLAND.

II.

HISTORY.

"L'invention d'iceluy," says Jacquinot [1545] of the Astrolabe,—"les uns l'ont attribuée à Mesahalach, les autres à Ptolomée, combien que longtemps auparavant avoit esté inventé d'Abraham on d'un nommé Lab, dont quelques-uns ont voulu dériver ce nom Astrolabe, comme du premier auteur."

It is amusing to read the old Frenchman's words: but even now there is no certainty as to the inventor of the Astrolabe. Ptolemy who may have got his idea about it very probably from Hipparchus, describes a planisphere in the 8th book of the Almagest, and the planispheric Astrolabe of the Arabs is a modification

* From *Astronomy and Astro-Physics*, No. 130.

of Ptolemy's planisphere; but the precise date of the first Astrolabe such as we are now considering, cannot be ascertained. It certainly, however, originated in the East, and was early used in India, Persia and Arabia. It became known in Europe by its introduction into Spain by the Arabs, and as the Arabian astronomers had excellent Astrolabes in the dark ages there is good reason for believing the instrument to be much older. The perfection of Arabic astronomical instruments about A. D. 700 was very great indeed.

We have evidence in various illuminated MSS of the astronomical use of the Astrolabe in Europe in the 13th century. A figure from one of these is reproduced on Plate XXIII which is of considerable interest, for not only is an Astrolabe shown in use, but the observer is represented with one of those *view-tubes* which have often—but erroneously—been taken for early telescopes. By the 14th century the Astrolabe was in general use in Europe; in the 16th and 17th centuries its use was universal. There were different forms of the instrument; but we know which one was most popular in the 16th century for Blundevile, writing in 1594, speaks thus of the Astrolabe of *Stöffler*,—"which for these hundred yeares or thereabouts, hath beene had in most price and estimation, as an instrument containing all the uses, or at least the most part of all other Mathematicall Instruments." The Astrolabe was only completely superseded at the beginning of the 18th century. The invention of Hadley's quadrant in 1731 gave it its death blow in Europe.

Europe adopted the Arabian Astrolabe. Indeed Astrolabes actually Arabian were common in Europe as late as the end of the 16th century. This is proved by the fact that E. Danti [1578] gives Arabic as well as Latin names in his tables of the fixed stars for the convenience of those who employed Arabian instruments. European makers, however, seem only to have produced Northern Astrolabes, and they very frequently added the piece known as the Label which is not found in oriental instruments. The derivation of the word Astrolabe from ἄστρον and λαβ is obvious. In the East the instrument is almost universally named the Usturláb.

The Astrolabe is essentially the same wherever its use has obtained. It only varies. One European variation is, however, of so much historical interest that it deserves a word of notice.

The spirit of maritime discovery stirred men mightily in the 15th century; but long ocean voyages called imperatively for improved instruments of navigation and especially for one for

finding latitude easily. A rude quadrant has been used by Diego Gomez for this purpose, but the adaptation of the astronomer's Astrolabe to mariner's use by Martin Behaim in 1480 was a distinct and important advance and one which Columbus keenly appreciated. It was the complement of the advance made towards the determination of latitude by the first publication of tables of the Sun's declination in 1475 by Regiomontanus in his *Calendarium Novum*. The Mariner's Astrolabe of Behaim was some 8 or 9 inches in diameter and of some thickness. A figure of such an instrument taken from Blundevile's work [1594] is given in Plate XXIII. A cross-staff of the same period and from the same work is also given.

The history of the Astrolabe is closely connected with that of Astrology. Nor is this surprising, considering the necessity astrologers were under of constantly observing the heavenly bodies in the practice of their calling. The handiness and comprehensiveness of the instrument could not fail to commend it to so shrewd a class of men. In the West astrology has practically disappeared. It has no basis that will bear scientific investigation. But it is well to remember that the requirements of judicial astrology led to the production of a great number of useful tables and observations. It is a fact worth noting that the first lunar tables constructed on the Newtonian Theory were intended for use in the calculation of nativities.

In the East—their birth quarter—both astrology and the Astrolabe still flourish. How amazingly they did flourish may be gathered from the statement of Marco Polo that in the city of Cambaluc alone, there were 5000 astrologers and soothsayers; and he mentions the Astrolabe as in use among them.

The amusing use of the Astrolabe described in the 161st night of the Arabian Nights is worth quoting once again because so typical of Eastern custom.

A young tailor had fallen desperately in love with the daughter of the Kádee of Bagdad and was looking forward with feverish impatience to visiting her. Naturally wishing to make the most favorable impression he decided to shave and go to the bath beforehand. So he sent for a barber, who instead of proceeding to the shaving, after an exasperating amount of talk, "took out a handkerchief and opened it; and lo, there was in it an Astrolabe consisting of seven plates; and he took it and went into the middle of the court where he raised his head towards the Sun, and looked for a considerable time; after which he said to me (the tailor), 'Know that there have passed of this our day,—which

is Friday, and which is the tenth of Safar, of the year 263 of the flight of the Prophet,—upon whom be the most excellent of blessings and peace!—and the ascendent star of which according to the required rules of the science of computation, is the planet Mars,—seven degrees and six minutes; and it happeneth that Mercury hath come in conjunction with that planet; and this indicateth that the shaving of the hair is now a most excellent operation.' (Arabian Nights, Lane's Trans., Vol. I, p. 331-2).

In the East of to-day as has been remarked the Astrolabe is frequently used. One use to which it is put by Mohammedans is to find the exact position of Mecca as regards the place of the observer. It may be remarked that Lane mentions (Arabian Nights, Vol. I, p. 384, note 57) that the Arabs sometimes use a plumb-line quadrant instead of the Astrolabe. Such an instrument would be essentially that figured in Plate XXIII, though there was much variety in the details of such quadrants. Many had rings for suspension; and many were solid, and engraved with considerable complexity.

To English speaking people it is of great interest that their classic Geoffrey Chaucer,—the Father of English poetry—wrote *A Treatise on the Astrolabe.* Of Astrolabes in Europe, I think it well to mention the following:

Two at Merton College, Oxford.

One at King's College Library, Cambridge,

Several at the S. Kensington Museum in the Oriental collections.

Twenty-eight at the British Museum. This collection, which is of great interest, includes the superb Shah Husian instrument. It is inscribed in Arabic. It is not fully perfect as it wants Rule, Horse, Fals and Cord.

Ten or eleven, some of them belonging to learned societies, are described by Mr. Morley in his work on the Astrolabe.

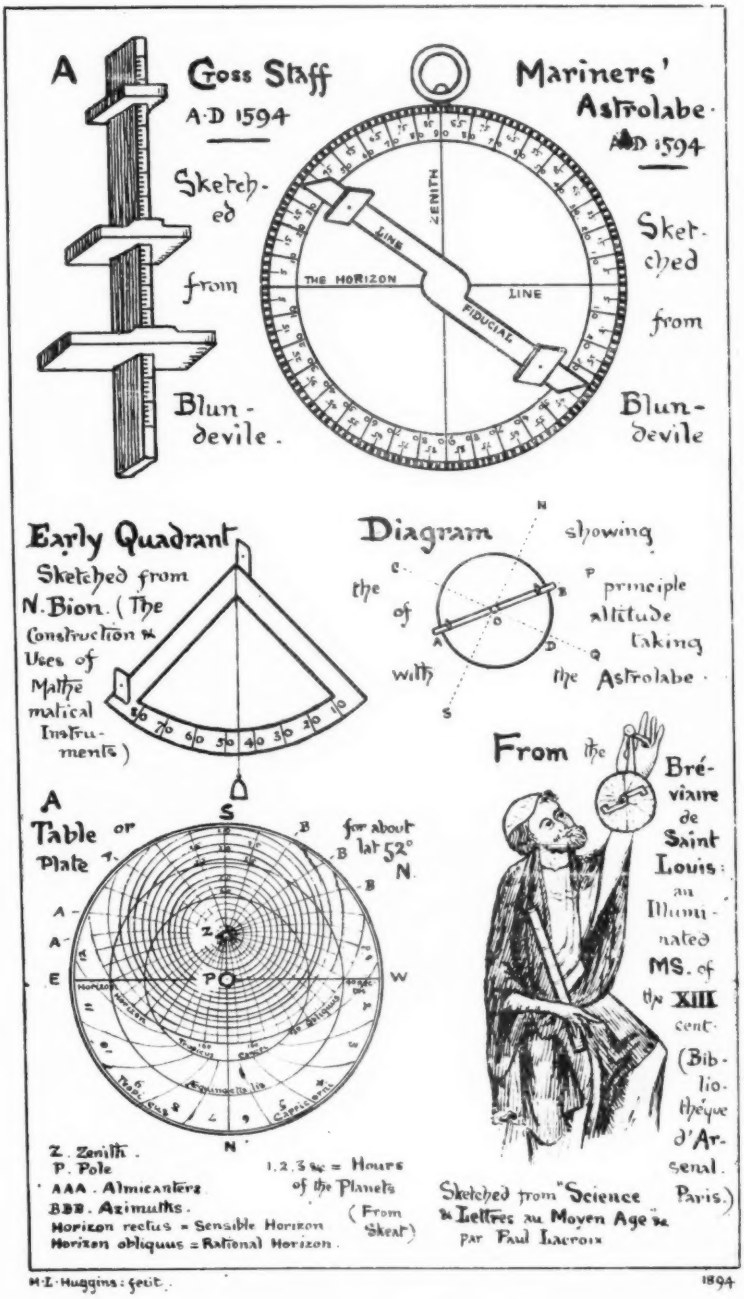
Eight were in the Spitzer collection of antiquities recently sold in Paris, and may be studied to some extent in the fine illustrated catalogues published of the collection.

Eleven (some very good specimens) were sold in London at Puttock and Simson's this spring.

One belongs to Mr. Knobel, F. R. A. S. This is perfect in all its parts, engraved in Kufic character, and is of the 13th century.

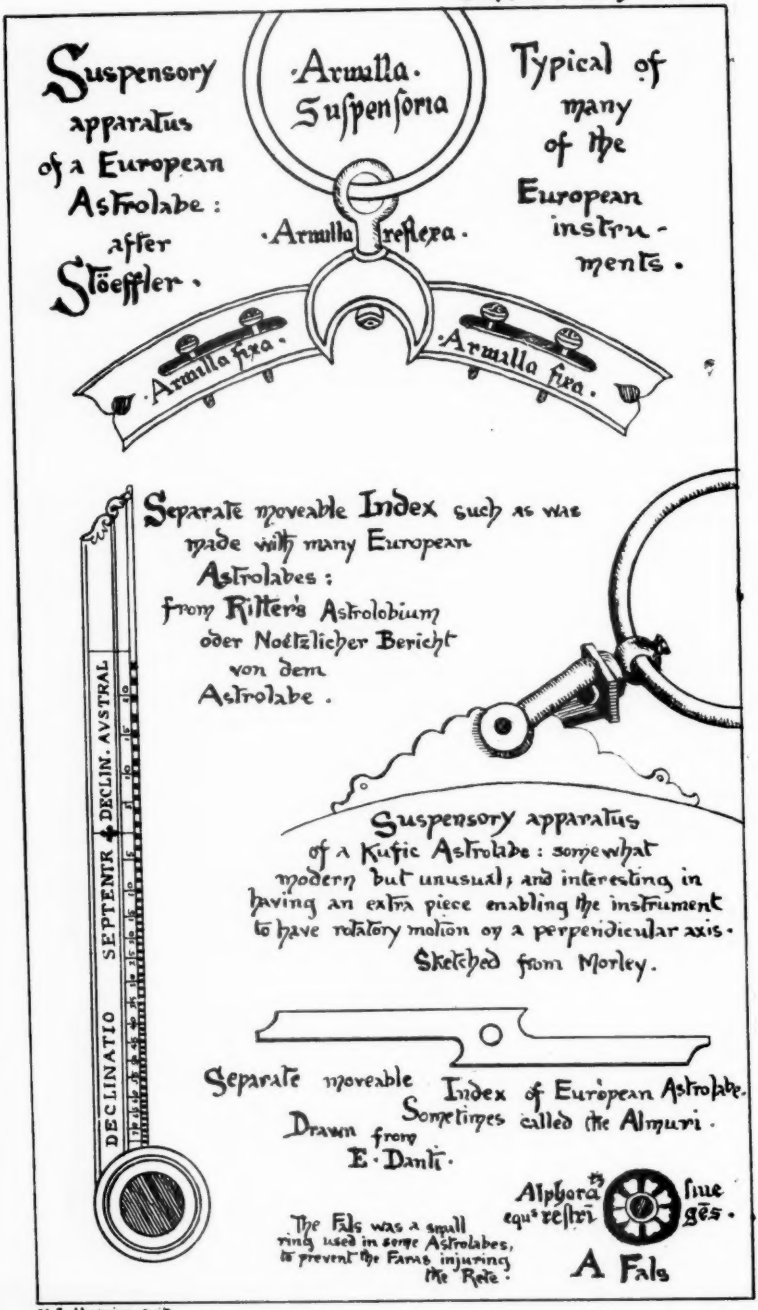
One is in the library at Nuremberg. This Astrolabe belonged to Regiomontanus.

One in the Bibliothéque Nationale, Paris. This was made A.



H.I. Huggins: fecit. 1894

Supplementary Plate.


Suspensory apparatus of a European Astrolabe: after Stöeffler.
·Armilla· Suspensoria
·Armilla reflexa·
Typical of many of the European instruments.
·Armilla fixa·
·Armilla fixa·
Separate moveable Index such as was made with many European Astrolabes: from Kilter's Astrolobium oder Nottzlicher Bericht von dem Astrolabe.
DECLINATIO SEPTENTR + DECLIN. AVSTRAL
Suspensory apparatus of a Kufic Astrolabe: somewhat modern but unusual; and interesting in having an extra piece enabling the instrument to have rotatory motion on a perpendicular axis. Sketched from Morley.
Separate moveable Index of European Astrolabe. Sometimes called the Almuri. Drawn from E. Danti.
Alphara equ. restri sive gēs.
The Fals was a small ring used in some Astrolabes, to prevent the Pins injuring the Rete.
A Fals
M·L·Huggins·fecit·

D. 905 and is the earliest Eastern Astrolabe known to us I believe.

One in a private collection in France, mentioned by Morley.

USE.

The principle upon which the use of the Astrolabe for altitude taking rests is obvious. Let the circle in the diagram (Plate XXIII) be considered as a solid flat fixed in one position with Rule attached to its centre round which it is free to move. If a horizon line CD drawn upon the circle points towards a point Q in the heavens in the plane of the circle, it is obvious that by turning the Rule AB towards any object P in the plane of the circle the angle BOB will be the angle subtended by P and Q at the eye or their angular distance on a globe, and this angle may be measured if the circumference of the circle be graduated: Thus if the plane of the circle pass through the poles N and S, and CD point towards the equator, then when the Rule points towards P, NOB, its N polar distance, or BOD, its declination, may be measured.

The mode of using the Astrolabe recommended by Chaucer is as follows:

"Put the ring of thyn Astrolabie up-on thy right thoumbe and turne thy left syde agayn the light of the sonne. And remeve thy rewle up and doun, till that the stremes of the sonne shyne thorgh bothe holes of thy rewle. Loke thanne how many degress thy rewle is areised fro the litel crois (east point) up-on thy est, and tak ther the altitude of thy sonne."

When the Astrolabe was to be used at sea "the observer was instructed to sit down and place himself with his back to the mainmast, hold the Astrolabe by the ring, hanging on the 2d finger of the left hand and move the *alidada* or *Label* up and down with the right until the Sun was on with both sights." (Markham).

The Sun was never observed directly through the sights. The stars were. In the better Astrolabes there were two pair of holes in the sights; a very small pair for solar observations; a larger pair for stellar ones.

Briefly, the Astrolabe was used for taking observations of the Sun, Moon and stars; for determining latitude; for determining approximately the points of the compass; for determinations of time; for measuring heights of mountains, buildings, and distances generally; for construction of horoscopes, and for many other operations connected with judicial astrology. In

the East, as has been stated, one of its very important uses was, and is, to find the exact position of Mecca as regards the place of the observer.

BIBLIOGRAPHY.

The best catalogue of works on the Astrolabe with which I am acquainted is that forming part of the *Bibliographie Générale de l'Astronomie* by *J. C. Houzeau* and *A. Lancaster*, pp. 630-649.

It appears to me that the most useful works on the whole to consult, are the following:

G. CHAUCER, [1391] *Treatise on the Astrolabe.*—Edition by W. W. Skeat in his edition of the Complete Works of Chaucer. Skeat's introduction, notes and illustrations to the treatise are all of the utmost value. A small book on Chaucer's Treatise by A. E. Brae is of interest.

J. J. STÖFFLER, [1512] *Elucidatio Fabrice ususque Astrolabii, etc.*—This work is very full and complete and has many excellent illustrations. It is, too, a beautiful book as regards printing, etc. There is a French translation of Stöffler's book by J. P. de Mesmes (published 1556). This work contains the text of Stöffler and the most necessary illustrations.

M. BLUNDEVILE, [1594] *His Exercises.*—Interesting and useful, and has good plates.

F. RITTER, [1599] *Astrolabium das ist, etc.*—Useful. Excellent plates.

W. H. MORLEY, [1856] *Description of a Planispheric Astrolabe constructed for Shah Husain, King of Persia.*—This work is much more than an admirable and exhaustive monograph on Shah Husain's Astrolabe. It contains besides an excellent account of Astrolabes generally, and has many useful notes. It is an invaluable work. The plates give Shah Husain's Astrolabe full size. This unfortunately makes the book awkward and unwieldy to use, but this is its only fault.

An account of the Astrolabe based on oriental information will be found in the *Voyages du Chev. Chardin en Perse* [1811] Tome IV, p. 335 *et seq.*

Among minor works may be mentioned an article in the *English Encyclopædia*, unsigned, but which I venture to think must have been written by the late Professor De Morgan.

Columbus by Clements Markham contains a little respecting the Mariner's Astrolabe.

THE SPECTROSCOPE IN ASTRONOMY.

TAYLOR REED.

FOR POPULAR ASTRONOMY.

We perceive a celestial body (unless it be a detonating meteor) by a single sense-sight. Our knowledge of it has but one vehicle—light. Most important it is that we examine this vehicle. For such inspection our sole instrument, practically, is the spectroscope. And from this analysis of light by the spectroscope we

learn the chemical nature of the body producing and sending the light; and after that its motion toward us or from us, if such motion be great enough.

The spectroscope was applied first to the Sun as the object easiest of study from abundance of light. At the advent of the spectroscope there were known of the Sun, the fundamental facts of its distance, diameter, mass and their dependent constants; the granular character of its surface; the spots and their various visual phenomena; as determined from the spots the Sun's rotation, varying with solar latitude; the faculæ; and at total eclipses prominences had been seen and the corona studied.

The spectroscope was first employed to find what chemical elements are contained in the Sun. Of the metals several were found at once; none of the non-metallic elements. Half a score of the metals were surely identified by the pioneers of spectroscopy. A little later hydrogen (hydrogen though gaseous is a metal) most prominently. And more recently many of the rarer metals. But now as at first most non-metals are absent or but doubtfully present. And some few lines in the Sun's spectrum can be produced by no known terrestrial substance.

The chemical constitution of the Sun has been the subject of much speculation; some of it almost controversy. Of this theorizing a little has been possibly directly profitable in increased knowledge; considerable of it indirectly in increased interest; not a little barren of both. Are all our elements present in the Sun, the non-metallic changed in form at the high temperature? Or are the non-metals really compounds at our low temperature, disrupted there into constituent elements? Or are they in whole or in part absolutely absent? For the present, probability is the chief basis of hypothesis.

The spectroscope was found to be most efficient in investigating sunspots. Would it tell how they came to be so dark? At first not; until increased optical power revealed the fact that the spot's spectrum, in certain regions at least, contains myriads of dark lines. Matter in gaseous state and colder than the general surface of the Sun must by its absorption cause part at least of the blackness of the spot.

A sunspot seems to be a region of disturbance, even to the eye, when its motion and variations are observed. What the eye indicates the spectroscope demonstrates. If the region about a spot is examined by the spectroscope it is usually found that certain points give a spectrum in which the hydrogen lines are displaced; that is, hydrogen at those points on the Sun is in motion

toward or from us. Steady observation has shown that around the spot the motion indicated is more often toward us (that is up from the Sun's surface); while just at the spot it is more often in the opposite direction. Matter seems to be thrown up from the surface of the Sun around the spot and to come down into the spot. The spot so seems to be the exact opposite of a volcano, that is to say, a sink.

Let the matter at a spot, not far from the edge of the Sun, be rotating. At the side of the spot next the Sun's equator the matter will be moving towards us or going from us; at the side next the Sun's pole in the opposite direction. Such motion the spectroscope shows occasionally; but not often.

These observations of movements at and in sunspots yield two chief theories of the physical nature of spots. One a considerable disturbance under the Sun's surface, of which the spot is one reresult; matter thrown up and coming down into the spot. The other, that the spot is a solar whirlpool—a storm—caused by the unequal rotation of the Sun.

Over the penumbra of every considerable spot and in other large and irregular areas on the Sun certain lines in the spectrum otherwise dark are turned bright. By observing one of these lines as the different parts of the Sun's surface are in turn examined the region where there are "faculæ" may be mapped; or, much better, photographed. Over the whole surface of the Sun are found these areas of faculæ, of increasing importance in the general theory of the physics of the Sun.

In the general rotation of the Sun one side is coming towards us while ths other is moving away. This the spectroscope should show, and does readily show, by displacement of the lines in the spectrum. This rotation is most rapid at the Sun's equator, and less rapid towards the pole; up to solar latitude 45°, beyond which point there are no spots. Is this law of slower rotation valid beyond latitude 45°? Here the spectroscope must give the answer, and at present its verdict is doubtful. The quantities involved are so minute that the greatest spectroscopic power and severe nicety of observation are required; for the problem is at the limit of the practical spectroscopy of to-day. On the whole the majority of evidence seems now to indicate that the rate of rotation does continue to decrease beyond latitude 45° toward the Sun's pole.

PRINCETON, N. J.

ON THE VARIABLE STARS OF SHORT PERIOD.

PAUL S. YENDELL.

III.

For Popular Astronomy.

Of the four stars in the present paper, three are of comparatively recent discovery, and are distinctly of the Eta Aquilæ type. The first two are both somewhat difficult to observe, and had better be left by the beginner until he has acquired skill and confidence by some months' practice on easier stars.

It has been thought best, in stating the mean light curves, to adhere in all cases to the original form of publication: Argelander and Schönfeld, with this class of stars, habitually begin with the minimum, and give the light-values for each successive hour until the next minimum: I have not considered it necessary to give these entire, stating only the value for each half or quarter-day except near the times of maximum and minimum, when intermediate hours are given.

The practice with most observers in this country has been to state the time in decimals of a day from the maximum phase, as has been done here with the first three stars. The curves are as heretofore, expressed in terms of the accompanying light-scale.

I have received inquiries as to the processes of observation, etc. All these will be found explained in Mr. Parkhurst's papers on the subject in Vol. I, from November, 1893, forward. With regard to charts, etc., the reader is referred to my former paper in the August number.

6404 Y Ophiuchi.

R. A. $17^h\ 47^m\ 17^s$ Decl. $-6°\ 7'.1$ (1900).

Elements of Variation.

Greenwich M. T.

Maximum 1882 Sept. $4.43 + 17d.12564$ E.

Minimum precedes maximum $6d.25$.

The variability of Y Ophiuchi was detected by Sawyer, in 1888; the original announcement of the fact may be found in the A. J., Vol. VIII, p. 138.

If we except Chandler's confirmation of its variability, the star has been observed, so far as I know, only by Sawyer and myself. It is difficult of observation, and the beginner is strongly recommended to let it alone until he has become familiar with the work

by some months' observation of the stars which have already been described. The field-glass should be used in observing it.

Sawyer's comparison-stars, magnitudes, light-scale and mean light-curve are as follows:

COMPARISON-STARS.

POSITIONS, 1875.

		h	m	s		°	′	Mag.	Lt. (steps)
a = 183 (U.A.) Ophiuchi	R. A.	17	50	11	Decl.	− 4	3.8	5.7	16.3
b = 187 " "		17	52	58		− 4	8.4	6.35	12.0
c = 167 " "		17	37	2		− 7	1.2	6.5	10.0
d = 194 " "		17	56	6		− 5	21.3	6.9	5.1
e = 178 " "		17	45	58		− 5	53.8	7.2	1.3

MEAN LIGHT-CURVE.

d	st.	d.	st.	d.	st.	d.	st.
− 6.25	3.7	− 1.50	9.2	+ 3.00	9.7	+ 7.50	5.6
6.00	3.7	1.00	11.5	3.50	9.0	8.00	5.1
5.50	3.7	− 0.50	12.0	4.00	8.5	8.50	4.7
5.00	4.0	± 0.00	12.0	4.50	8.1	9.00	4.3
4.50	4.4	+ 0.50	12.0	5.00	7.7	9.50	4.1
4.00	5.0	1.00	11.9	5.50	7.4	10.00	3.8
3.50	5.6	1.50	11.7	6.00	7.0	10.50	3.7
3.00	6.5	2.00	11.3	6.50	6.5	11.00	3.7
2.50	7.3	+ 2.50	10.6	+ 7.00	6.0	11.50	3.7
− 2.00	8.0						

6984 U. AQUILÆ.

R. A. $19^h\ 23^m\ 58^s$ Dec. − 7° 15′.0 (1900).

ELEMENTS OF VARIATION.

GREENWICH M. T.

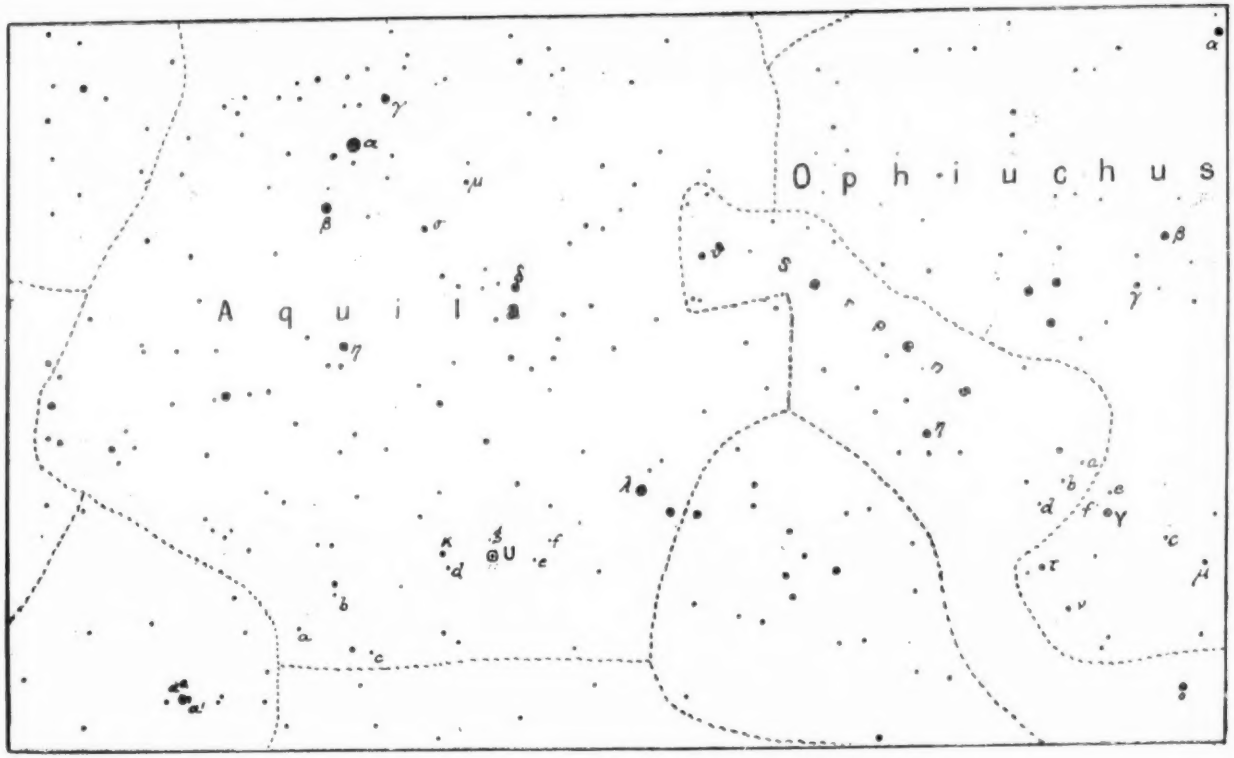
Maximum 1886, Sept. 20.146 + 7*d*.02645 E.

Minimum precedes Maximum 2*d*.12.

The variability of U Aquilæ was discovered by Sawyer in 1886, in the course of his work in the revision of the Uranometria Argentina magnitudes.

It is less easy of identification and observation than most of the preceding stars, but with the aid of the charts, can be found without too much difficulty, and will identify itself by its changes in the course of a few evenings' observation; a field-glass is required for observing it.

The comparison-stars, light-scale and mean curve here given are Sawyer's: see A. J., Vol. XIIII, p. 85.



Identification Chart for U Aquilæ and Y Ophiuchi.

Comparison-Stars.

Positions for 1875.

		h	m	s		°	′	Mag.	Lt.(steps)
a =	100 (U.A.) Aquilæ	R. A. 19	52	29	Dec. −	10	17.0	6.15	19.5
b =	92 " "	19	47	21	−	8	53.8	6.25	16.2
c =	80 " "	19	42	9	−	11	10.7	6.35	14.6
d =	" "	19	28	45	−	7	43.9	6.65	11.2
e =	" "	19	16	20	−	7	38.2	6.70	9.0
f =	Weisse's Bessel 280	19	13	19	−	6	51.5	7.10	5.0
g =	" " 568	19	24	12	−	6	46.2	7.5	0.0

Mean Light-Curve.

d.	st.	d.	st.	d.	st.	d.	st.
− 2.12	2.8	− 0.25	14.1	+ 1.50	11.3	+ 3.25	5.7
2.00	2.9	0.00	15.4	1.75	10.5	3.50	5.1
1.75	3.2	+ 0.25	15.1	2.00	9.5	3.75	4.4
1.50	3.9	0.50	14.6	2.25	8.6	4.00	3.7
1.25	5.1	0.75	13.9	2.50	7.7	4.25	3.2
1.00	6.3	1.00	13.2	2.75	7.0	4.50	3.0
0.75	8.2	+ 1.25	12.3	+ 3.00	6.4	4.75	2.8
− 0.50	10.5					+ 5.00	2.8

7483 T Vulpeculæ.

R. A. $20^h\ 47^m\ 13^s$ Decl. + 28° 52′.5 (1900).

Elements of Variation.

Greenwich m. t.

Maximum 1885 Nov. 2.95 + 4*d*.4362 E.

Minimum precedes maximum 1*d*.3.

Found to be variable by Sawyer in 1885. Confirmed by Chandler.

It is one of the most interesting of the short-period variables, and has been pretty constantly observed by its discoverer and myself.

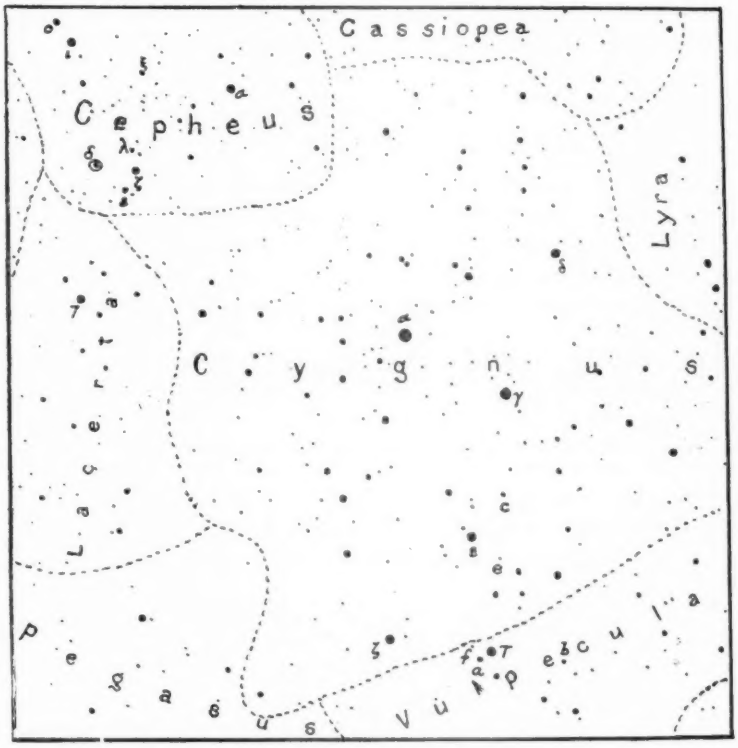
On account of the shortness of the period, the mean curve has generally to be used in determining the phases from the observations; and from its steady and rapid increase, the maximum may be very accurately determined if one or two observations can be obtained during the rise: so that it is well to give such observations extra weight in reducing, though, for simplicity's sake, this was not done in the example given in the first paper of this series.

The star can be observed with the opera-glass, though the writer finds the field-glass more convenient.

The comparison-star appears to me to be variable, but this is not borne out by the observations of Chandler or Sawyer; without making special observations to this end, which is a thing a beginner should not do, it may be well to watch the light-scale

for indications, all of which, however, should be accepted only with great reserve.

The comparison-stars are as follows; the scale and mean curve are my own, the latter agreeing very closely with Sawyer's.



INDENTIFICATION CHART, δ CEPHEI AND T VULPECULÆ.

COMPARISON-STARS.

POSITION 1855.

								Light
		h	m	s		°	′	Mag.	(Steps).
a = F 32 Vulpeculæ	R. A.	20	48	24	Decl. +	27	30.0	5.27	13.8
b = " 27 "		20	30	18		25	57.5	5.7	9.3
c = " 47 Cygni		20	34	36		29	17.5	6.17	4.75
f = D. M. + 27° 3909		20	48	13		27	58.3	6.7	0.00

MEAN LIGHT-CURVE.

d.	st.	d.	st.	d.	st.	d.	st.
− 1.30	1.94	− 0.25	8.16	+ 1.00	5.78	+ 2.25	2.66
1.25	1.95	± 0.00	9.78	1.25	4.93	2.50	2.37
1.00	2.50	+ 0.25	8.73	1.50	4.13	2.75	2.12
0.75	4.20	0.50	7.67	1.75	3.44	3.00	1.96
− 0.50	6.10	+ 0.75	6.66	+ 2.00	2.96	+ 3.14	1.94

8073 δ CEPHEI.

R. A. $22^h\ 25^m\ 27^s$ Decl. + 57° 54′.2 (1900).

ELEMENTS OF VARIATION.

GREENWICH M. T.

Maximum 1840 Sept. $26d\ 10^h\ 50^m + 5d\ 8^h\ 47^m\ 39^s.3$ E

$- 0^s.0008\ E^2 - 0^s.00000015\ E^3$.

Minimum precedes maximum $1d\ 14^h\ 36^m$.

This is one of the oldest and best-known of the variable stars; its variability was discovered by Goodricke in 1784, and it has been observed pretty thoroughly by most of those observers who have busied themselves with the variables, down to Argelander and Schönfeld, whose observations cover the interval from 1840 to 1865 at least. The two latter have published elaborate discussions of all the observations to 1865, and the mean curve and scale given below are those of Schönfeld, taken from his paper in the A. N., Vol. 75, pp. 15-18.

This star is especially recommended to the beginner, as it is very readily identified, with its comparison-stars, and easy of observation; in the absence of moonlight, it can be observed with the naked eye.

In this latitude it never sets, and is high enough in the evening for observation for at least eight months in the year.

The comparison-stars and light-scale are:

POSITIONS FOR 1855.

		h	m	s		°	′	Mag.	Light (Steps).
ε = ε Cephei	R. A.	22	9	43.5	Decl.	+ 56	19.3	4.7	1.9
a = 7 Lacertæ		22	25	19		+ 49	32.2	4.3	6.6
ι = ι Cephei		22	44	32		+ 65	25.9	3.9	10.9
ζ = ζ "		21	5	50		+ 57	29.3	3.8	12.4

MEAN LIGHT-CURVE.

Argument: the time from the last minimum.

	0*d*.	1*d*.	2*d*.	3*d*.	4*d*.	5*d*.
0h	2.98	7.69	9.37	7.26	4.73	3.24
6	3.13	9.57	8.55	6.47	4.28	3.01
9	—	—	—	—	—	2.98
12	3.73	10.37	7.94	5.79	3.90	
13	—	10.41	—	—	—	
14	—	10.41	—	—	—	
18	5.20	10.15	7.80	5.24	3.54	

DORCHESTER, Mass., 1894, Dec. 18.

PLANET NOTES FOR MARCH.

H. C. WILSON.

Mercury having passed inferior conjunction in the latter part of February will move rapidly to his greatest western elongation, reaching that point on the morning of March 24, when he will be 27° 48′ distant from the Sun. This will be a time when the early rising amateur astronomer may see the planet as "morning star." The waning Moon will have passed the planet, at almost the same declination, on the previous evening, so that on the morning of the 24th the planet will be about 6° or 7° to the west of the Moon.

Venus is "evening star" and her brightness, although less than one third of that at maximum, is such as to make her more conspicuous than any of the stars. Her course will be northeastward through Pisces and Aries. The Moon and Venus will be in conjunction on the evening of March 28 at $5^h\ 38^m$ Central time.

Mars may be observed in the early part of the night. He will be in conjunction with the Moon March 3 and March 31. His course is eastward through Taurus.

Jupiter is near the horns of Taurus and north of the bright constellation of Orion. This region of sky is always noticeable for the brilliancy of its celestial gems, with Capella toward the north, the Gemini and Procyon to the east, Sirius and the whole group of Orion stars to the south, Aldebaran, the Hyades and Pleiades, and now Mars, to the west and the Milky Way as a background, but with Jupiter to crown the centre the beauty of the glittering array on these frosty winter nights is incomparable. Jupiter will be at quadrature, 90° east from the Sun March 17. The Moon passes by this planet on the morning of March 5.

Saturn may be seen toward the southeast after 10 o'clock in the evening, but is hardly yet in convenient position for the amateur. The rings this year are turned up at an angle of from 16° to 18° to the line of sight, so that we shall see them much more plainly than during last year. Saturn is in the constellation Libra about 15° east from Spica (α Virginis). The Moon will pass by him on the morning of March 14.

Uranus is in Libra southeast from Saturn and a little east of the star ν.

Neptune is in Taurus not far from the star ι. Mars will pass by him, 3° 1′ to the north, at 9 A. M. March 25. Neptune will be at quadrature March 3.

Planet Tables for March.

[The times given are local time for Northfield. To obtain Standard Times for places in approximately the same latitude, add the difference between Standard and Local Time if west of the Standard Meridian or subtract if east].

MERCURY.

Date.	R. A.	Decl.	Rises.	Transits.	Sets.
	h m	° ′	h m	h m	h m
Mar. 5.....	22 0.9	− 9 26	5 41 A. M.	11 8.1 A. M.	4 35 P. M.
15.....	22 4.6	− 11 33	5 14 "	10 32.4 "	3 51 "
25.....	22 37.4	− 10 18	5 2 "	10 25.8 "	3 49 "

VENUS.

Mar. 5.....	0 29.5	+ 2 9	7 23 A. M.	1 36.3 P. M.	7 49 P. M
15.....	1 14.6	+ 7 17	7 9 "	1 41.9 "	8 15 "
25.....	2 0.3	+ 12 8	6 55 "	1 48.1 "	8 42 "

MARS.

Mar.	5.....	3	59.6	+ 22	8	9	33	A. M.	5	12.0	P. M.	12	51	A. M.
	15.....	4	24.0	+ 23	11	9	6	"	4	50.8	"	12	35	"
	25.....	4	49.1	+ 24	1	8	47	"	4	36.6	"	12	26	"

JUPITER.

Mar.	5.....	5	45.1	+ 23	22	11	5	A. M.	6	51.0	P. M.	2	37	A. M.
	15.....	5	47.7	+ 23	24	10	29	"	6	14.3	"	2	0	"
	25.....	5	51.6	+ 23	26	9	53	"	5	38.8	"	1	25	"

SATURN.

Mar.	5.....	14	21.8	− 11	21	10	7	P. M.	3	26.3	A. M.	8	46	A. M.
	15.....	14	20.3	− 11	11	9	26	"	2	45.5	"	8	5	"
	25.....	14	18.3	− 10	59	8	43	"	2	4.2	"	7	25	"

URANUS.

Mar.	5.....	15	10.1	− 17	23	11	21	P. M.	4	14.5	A. M.	9	8	A. M.
	15.....	15	9.5	− 17	20	10	41	"	3	34.6	"	8	28	"
	25.....	15	8.6	− 17	17	10	1	"	2	54.4	"	7	48	"

NEPTUNE.

Mar.	5.....	4	47.2	+ 20	55	10	20	A. M.	5	53.3	P. M.	1	27	A. M.
	15.....	4	47.6	+ 20	56	9	41	"	5	14.4	"	12	48	"
	25.....	4	48.2	+ 20	58	9	2	"	4	35.7	"	12	9	"

THE SUN.

Mar.	5.....	23	4.6	−	5	56	6	30	A. M.	12	11.6	P. M.	5	53	P. M.
	15.....	23	41.4	−	2	1	6	12	"	12	9.0	"	6	6	"
	25.....	0	17.8	+	1	56	5	54	"	12	6.0	"	6	18	"

Occultations Visible at Washington.

Date 1894		Star's Name.	Magnitude.	IMMERSION. Washington M. T.	IMMERSION. Angle from N p't.	EMERSION. Washington M. T.	EMERSION. Angle from N p't.	Duration.
				h m	°	h m	°	h m
Mar.	1	B.A.C. 782	7.0	7 59	120	8 44	203	0 45
	5	49 Aurigæ	5.7	11 16	80	12 13	309	0 57
	7	γ Cancri	4.3	11 58	128	13 1	281	1 3
	10	80 Cancri	6.8	6 39	100	7 34	319	0 55
	13	B.A.C. 4722	5.8	13 00	123	14 16	309	1 16
	17	γ^1 Sagittarii	5—6.5	15 22	118	16 41	257	1 19
	31	W. iv, 1421	6.0	8 38	57	9 29	310	0 51

Phases and Aspects of the Moon.

		Central Time. h	m	
First Quarter	Mar.	4	6	40 A. M.
Perigee		9	6	36 P. M.
Full Moon		10	9	38 "
Last Quarter		17	11	32 "
Apogee		22	12	36 A. M.
New Moon		26	4	25 "

Jupiter's Satellites for March.

Phases of the Eclipses of the Satellites for an Inverting Telescope.

Configurations at 8h 30m for an Inverting Telescope.

Day.	West.	East.
1	·4· ·2 ○3· 1·	
2	4· 3· ·1 ○ ·2	
3	4· ·3 ○2· 1·	
4	·4 2· ·1○	
5	○1· ·4 ○	·2● ·3●
6	·4 ○ ·1 2· ·3	
7	2· ·1 ·4 ○ 3·	
8	·2 ○ 3· ·1 ·4	
9	3· ·1 ○ ·2 ·4	
10	3· ○ 2·1· ·4	
11	·32· ·1 ○ ·4	
12	○1· ○ 4· ·3● ·2●	
13	○ ·2 ·3 4· ·1●	
14	2· ○ 4·	
	1· 3	
15	·2 ○ 4·	
	·1 3·	
16	3· 4· ○ ·2	
	·1	
17	4· ○ 2·	
	3· ·1·	
18	4· ·3 2· ·1 ○	
19	4· 2· ○ 1·	
	·3	
20	·4 ○ ·2 3	·1●
21	·4 2· ○ 3·	
	1·	
22	·4 ·2 ○ ·1 3·	
23	·4 ·13· ○ ·2	
24	○2· ·3 ○ 2·	·4●
	1	
25	·3 2· ·1 ○ ·4	
26	2· ○ ·1 ·4	
	·3	
27	·1○ 2· ·4	
	3	
28	○1· ○2· ○ ·3 ·4	
29	·2· ○ ·1 3· 4·	
30	1· 3· ○ ·2 4·	
31	3. ○ ·12· 4·	

Phenomena of Jupiter's Satellites.

Central Time.

Mar.	1	12	1 P. M.	I	Ec. Re.
	2	12	6 A. M.	III	*Tr. In.
		3	0 "	III	Tr. Eg.
		3	50 "	II	Oc. Dis.
		5	8 "	III	Sh. In.
		5	46 "	I	Tr. In.
		7	1 "	I	Sh. In.
		8	2 "	I	Tr. Eg.
		8	10 "	III	Sh. Eg.
		8	56 "	II	Ec. Re.
		9	18 "	I	Sh. Eg.
	3	2	59 "	I	Oc. Dis.
		6	30 "	I	Ec. Re.
		10	28 P. M.	II	*Tr. In.
	4	12	14 A. M.	I	*Tr. In.
		2	56 "	II	*Sh. In.
		1	6 "	II	*Tr. Eg.
		1	30 "	I	Sh. In.
		2	30 "	I	Tr. Eg.
		3	37 "	II	Sh. Eg.
		3	47 "	I	Sh. Eg.
		9	27 P. M.	I	Oc. Dis.
	5	12	59 A. M.	I	Ec. Re.
		1	53 P. M.	III	Oc. Dis.
		4	47 "	III	Oc. Re.
		5	5 "	II	Oc. Dis.
		6	42 "	I	*Tr. In.
		7	04 "	III	*Ec. Dis.
		7	59 "	I	*Sh. In.
		8	58 "	I	*Tr. Eg.
		9	58 "	III	*Ec. Re.
		10	14 "	II	*Ec. Re.
		10	16 "	I	*Sh. Eg.
	6	3	56 "	I	Oc. Dis.
		7	28 "	I	*Ec. Re.
	7	11	45 A. M.	II	Tr. In.
		1	10 P. M.	I	Tr. In.
		2	15 "	II	Sh. In.
		2	23 "	II	Tr. Eg.
		2	27 "	I	Sh. In.
		3	27 "	I	Tr. Eg.
		4	44 "	I	Sh. Eg.
		4	57 "	II	Sh. Eg.
	8	1	22 A. M.	IV	Oc. Dis.
		2	33 "	IV	Oc. Re.
		10	24 "	I	Oc. Dis.
		1	23 P. M.	IV	Ec. Dis.
		1	57 "	I	Ec. Re.
		3	18 "	IV	Ec. Re.
	9	3	58 A. M.	III	Tr. In.
		6	21 "	II	Oc. Dis.
		6	52 "	III	Tr. Eg.
		7	39 "	I	Tr. In.
		8	56 "	I	Sh. In.
		9	08 "	III	Sh. In.
		9	55 "	I	Tr. Eg.
		11	13 "	I	Sh. Eg.
		11	31 "	II	Ec. Re.
		12	10 P. M.	III	Sh. Eg.
	10	4	53 A. M.	I	Oc. Dis.
		8	26 "	I	Ec. Re.
	11	1	02 "	II	*Tr. In.
Mar.	11	2	07 A. M.	I	Tr. In.
		3	25 "	I	Sh. In.
		3	35 "	II	Sh. In.
		3	41 "	II	Tr. Eg.
		4	24 "	I	Tr. Eg.
		5	42 "	I	Sh. Eg.
		6	16 "	II	Sh. Eg.
		11	22 P. M.	I	*Oc. Dis.
	12	2	55 A. M.	I	Ec. Re.
		5	48 P. M.	III	*Oc. Dis.
		7	38 "	II	*Oc. Dis.
		8	36 "	I	*Tr. In.
		8	43 "	III	*Oc. Re.
		9	53 "	I	*Sh. In.
		10	52 "	I	*Tr. Eg.
		11	05 "	III	*Ec. Dis.
	13	12	11 A. M.	I	*Sh. Eg.
		12	49 "	II	Ec. Re.
		1	59 "	III	Ec. Re.
		5	50 P. M.	I	*Oc. Dis.
		9	24 "	I	*Ec. Re.
	14	2	21 "	II	Tr. In.
		3	04 "	I	Tr. In.
		4	22 "	I	Sh. In.
		4	53 "	II	Sh. In.
		4	59 "	II	Tr. Eg.
		5	21 "	I	Tr. Eg.
		6	40 "	I	*Sh. Eg.
		7	35 "	II	*Sh. Eg.
	15	12	19 "	I	Oc. Dis.
		3	53 "	I	Ec. Re.
	16	7	53 A. M.	III	Tr. In.
		8	55 "	II	Oc. Dis.
		9	33 "	I	Tr. In.
		10	24 "	IV	Tr. In.
		10	49 "	III	Tr. Eg.
		10	51 "	I	Sh. In.
		11	45 "	IV	Tr. Eg.
		11	49 "	I	Tr Eg.
		1	07 P. M.	III	Sh. In.
		1	09 "	I	Sh. Eg.
		2	07 "	II	Ec. Re.
		4	11 "	III	Sh. Eg.
		10	27 "	IV	*Sh. In.
	17	12	37 A. M.	IV	*Sh. Eg.
		6	48 "	I	Oc. Dis.
		10	21 "	I	Ec. Re.
	18	3	40 "	II	Tr. In.
		4	01 "	I	Tr. In.
		5	20 "	I	Sh. In.
		6	13 "	II	Sh. In.
		6	18 "	II	Tr. Eg.
		6	18 "	I	Tr. Eg.
		7	37 "	I	Sh. Eg.
		8	55 "	II	Sh. Eg.
	19	1	17 "	I	Oc. Dis.
		4	50 "	I	Ec. Re.
		9	47 P. M.	III	*Oc. Dis.
		10	12 "	II	*Oc. Dis.
		10	30 "	I	*Tr. In.
		11	48 "	I	*Sh. In.
	20	12	43 A. M.	III	Oc. Re.

Mar.	20	12	47	A. M.	I	Tr. Eg.	Mar.	26	3	13	A. M.	I	Oc. Dis.
		2	06	"	I	Sh. Eg.			6	46	"	I	Ec. Re.
		3	06	"	III	Ec. Dis.		27	12	26	"	I	Tr. In.
		3	24	"	II	Ec. Re.			12	48	"	II	Oc. Dis.
		6	02	"	III	Ec. Re.			1	44	"	I	Sh. In.
		7	46	P. M.	I	*Oc. Dis.			1	51	"	III	Oc. Dis.
		11	19	"	I	*Ec. Re.			2	43	"	I	Tr. Eg.
	21	4	59	"	II	Tr. In.			4	01	"	I	Sh. Eg.
		4	59	"	I	Tr. In.			4	48	"	III	Oc. Re.
		6	17	"	I	Sh. In.			6	00	"	II	Ec. Re.
		7	16	"	I	Tr. Eg.			7	06	"	III	Ec. Dis.
		7	32	"	II	Sh. In.			10	03	"	III	Ec. Re.
		7	37	"	II	Tr. Eg.			9	42	P. M.	I	*Oc. Dis.
		8	35	"	I	*Sh. Eg.		28	1	15	A. M.	I	Ec. Re.
		10	14	"	II	*Sh. Eg.			6	55	P. M.	I	*Tr. In.
	22	2	15	"	I	Oc. Dis.			7	38	"	II	*Tr. In.
		5	48	"	I	*Ec. Re.			8	12	"	I	*Sh. In.
	23	11	28	A. M.	I	Tr. In.			9	12	"	I	*Tr. Eg.
		11	30	"	II	Oc. Dis.			10	10	"	II	*Sh. In.
		11	54	"	III	Tr. In.			10	18	"	II	*Tr Eg.
		12	46	P. M.	I	Sh. In.			10	30	"	I	*Sh. Eg.
		1	45	"	I	Tr. Eg.		29	12	52	A. M.	II	Sh. Eg.
		2	50	"	III	Tr. Eg.			4	14	P. M.	I	Oc. Dis.
		3	02	"	I	Sh. Eg.			7	44	"	I	*Ec. Re.
		4	42	"	II	Ec. Re.		30	1	24	"	I	Tr. In.
		5	07	"	III	Sh. In.			2	07	"	II	Oc. Dis.
		8	12	"	III	*Sh. Eg.			2	41	"	I	Sh. In.
	24	8	44	A. M.	I	Oc. Dis.			3	41	"	I	Tr. Eg.
		12	17	P. M.	I	Ec. Re.			3	59	"	III	Tr. In.
		7	13	"	IV	*Oc. Dis.			4	58	"	I	Sh. Eg.
		8	44	"	IV	*Oc. Re.			6	57	"	III	*Tr. Eg.
	25	5	57	A. M.	I	Tr. In.			7	18	"	II	*Ec. Re.
		6	18	"	II	Tr. In.			8	07	"	III	*Sh. In.
		7	15	"	I	Sh. In.		31	12	14	A. M.	III	Sh. Eg.
		7	25	"	IV	Ec. Dis.			10	41	"	I	Oc. Dis.
		8	14	"	I	Tr. Eg.			2	13	P. M.	I	Ec. Re.
		8	51	"	II	Sh. In.	Apr.	1	7	53	A. M.	I	Tr. In.
		8	57	"	II	Tr. Eg.			8	59	"	II	Tr. In.
		9	32	"	I	Sh. Eg.			9	10	"	I	Sh. In.
		9	35	"	IV	Ec. Re.			10	11	"	I	Tr. Eg.
		11	33	"	II	Sh. Eg.							

NOTE.—In., denotes ingress; Eg., egress; Dis., disappearance; Re., reappearance; Ec., eclipse. Oc., denotes occultation; Tr., transit of the satellite; Sh. transit of the shadow; * Visible at Washington.

COMET NOTES.

Comet *e* 1894 (Edward Swift).—We have tried hard on three clear nights in January to again see this comet but failed. We yet hope that some observers with larger telescopes may be able to get the desired observations.

Encke's Comet.—This comet is quite bright, almost visible to the naked eye. On Jan. 15 it had a faint tail which could be traced to a distance of a degree and a half from the nucleus. On Jan. 16 at 7 P. M. Central time it was on a parallel with α Aquarii, following closely the path prescribed by the ephemeris in our last number. By the time this reaches our readers the comet will have passed too nearly in line with the Sun to be visible, but it will reappear on the other side and be visible in the morning during February. It will be best seen from the southern hemisphere.

Encke's Comet.—Last evening I obtained a very important observation of Encke's comet. It was one of those matchless evenings that are the joy and delight of every astronomer; the atmosphere was steady, clear and pure, so that faint objects could be seen almost to the very horizon. The comet was about ten degrees above the horizon at $6^h\ 45^m$. Since writing my note of January 3, the comet has been very rapidly increasing in brightness, so that it is now near the limit to naked-eye visibility; an effort was made to see it with the naked eye, but am not certain that I saw it, I could sometimes catch a whitish object in the comet's place. The comet has somewhat diminished in apparent diameter since my first observations, and now appears very nearly round with increasing density toward the center, which is a distinct stellar nucleus. But the most interesting part of all, is its wonderful tail. This was seen for the first time last evening, although on the preceding evening I observed the comet but no tail was noticed. I could trace the tail for at least a degree from the head, or a little past α Aquarii. It was slightly curved to the southward, and was a little wider at the outer end. The tail was much brighter for a half degree from the head, and had several bright patches or condensations in it; one about 15′ (eye estimation), another about 25′, and a fainter doubtful one at 40′ from head. Just before the third or outer condensation there appeared to be almost a break in the tail, the nebulosity joining the two parts being extremely faint. At my earlier observations in December, a nucleus was at times seen, but as I thought there might be a doubt in regard to it, I did not mention it in my former notes. The nucleus was situated in the northeast end of the elongated condensation; this made me doubt its reality, but as it was seen on several successive evenings, it was not a star. The power used in these observations was 27, and in this last mentioned matter regarding the suspected nucleus with a power of 55. W. E. SPERRA.

Randolph, Ohio, January 18, 1895.

PRACTICAL SUGGESTIONS.

86. Glass specula are generally coated with silver to a depth of one-two hundred thousandth of an inch. Could this film be made much thicker to advantage? How thick could it be made without imparing its qualities by the chemical process?

I understand that there is a method in use for silvering small mirrors electrolytically. What is the process? In books on Electro-metallurgy it is stated that by adding a few drops of carbon-bi-sulphide to the ordinary cyanide or thio-sulphate plating solution, a bright surface may be obtained, which requires no burnishing. Is this surface susceptible of a high polish, fine enough for optical purposes? W. B. F.

Answers:—Glass specula may be coated very much heavier than one-two hundred thousandth of an inch by making the solution stronger. When about one-two hundred thousandth of an inch thick, the silver film transmits the blue rays, but by making the solutions twice as strong the deposit becomes practically opaque when the silvering is well done. It may also be made still heavier by silvering *twice*, but only one with much experience is likely to succeed by this method as no part of the surface must be allowed to dry between the first and second coat and great care must be taken that the silver does not bleach.

For a silvered glass reflector for a telescope, there is no need to put on a coat heavier than one one hundred thousandth of an inch.

I do not know of any method of depositing silver on glass by an electrical current in a solution of carbon-bi-sulphide. I should think it would be entirely inadmissible as the sulphur would almost immediately ruin the polish of the silver. Mirrors are silvered electrolytically both in this country and in Germany, but the process is a very costly one and requires expensive apparatus. It must be done in a high vacuum and up to this time it is a difficult matter to silver mirrors over 5-inches in diameter. They are silvered so readily and cheaply by chemical processes that for such surfaces it seems useless to go to such an expense.

J. A. B.

87. **Note on the use of Ammonia for Cleaning polished surfaces.**—I can confirm the experience of Mr. Brashear in regard to the value of ammonia in cleaning surfaces of polished steel.

A word of caution however is necessary in this connection. At one time this substance was used in cleaning the surface of a glass bar upon which had been traced a meter subdivided to millimeters, and in the investigation of which, a good deal of time had been spent. After only a slight rubbing of the surface with chamois skin, saturated with ammonia, every line disappeared as completely as if they had never been traced.

W. A. R.

88. **The Signification of the Constant** k.—In the reply of your correspondent H. to the inquiry in regard to the signification of the constant k in the equation $F = k\frac{M_1 M_2}{d^2}$, the statement is made that this constant is not a quantity which is peculiar to the Earth.

Is it not true that in this case k is simply the abstract number required to convert proportionality into equality? Newton always wrote the relation in the form, F varies as $\frac{M_1 M_2}{d^2}$. Now $\frac{M_1 M_2}{d^2}$ is either equal to, greater than or less than F. If the two expressions are not equal, equality can be established by multiplying the second member by such a number as will make them equal. This quantity is usually designated by the letter k.

This constant must be distinguished from the Gaussian constant k, which is a true gravitational constant. The constant referred to, is really a mass-constant and not a constant of planetary motion.

Inasmuch as these constants give the general student a good deal of trouble, it may be worth while to determine their numerical values.

DETERMINATION OF THE CONSTANT OF MASS.

Let m_1 = the mass whose weight at the surface of the Earth is 1 gramme.
m_e = the mass of the Earth, collected at its center of gravity, expressed in grammes.
$d = r$ = the radius of the Earth.
f = the unit of force in the G. G. S. system = 981 dynes.

We have $m_1 = 1$

$$r = 3959 \times 5280 \times 12 \times 2.54 = 63714 \times 10^4 \text{ centimeters}$$

Then,
$$981 = k\frac{m_1 m_2}{d^2}$$

Whence:—
$$k = \frac{981\ [63714 \times 10^4]^2}{614 \times 10^{25}}$$

$$= \frac{1}{15418000} = 0.0000006486.$$

It appears, therefore, that the value of k depends upon the measured value of the mean radius of the Earth and upon the mass of the Earth. Since neither of these elements is known with precision it is obvious that this constant cannot at present be considered a constant of nature. It appears, also, that the astronomical unit of mass is 15418000 grammes and that the corresponding unit of force is 15418000 dynes.

DETERMINATION OF THE GAUSSIAN CONSTANT OF PLANETARY MOTION.

We have from Gauss; Theoria Motus page 2

$$k = \frac{2\pi}{T\sqrt{1+m_2}}$$

in which:—

T = the length of the sidereal year for the Earth = 365.2563835 days.
1 = the mass of the Sun.
m_2 = the mass of the Earth = 0.0000028192.

Whence:—

$k = 0.01720209895.$
$\log k = 8.2355814$ in parts of the radius.
$\log k'' = 3.5500066$ in seconds of arc.

We will now make use of these constants in the computation of the mass of Jupiter.

(1).

Computation of the mass of Jupiter from the Gaussian equation:

$$\text{Mean daily motion of Jupiter} = \mu = \frac{k''\sqrt{1+m_3}}{a^{\frac{3}{2}}}$$

Data from Young's Astronomy page 529.

$a = 5.20280$. $T = 4332.5800$ days. $m_3 = \frac{1}{1048}$. $\mu = \frac{360^\circ}{4332.5800} = 299''.129$.

$$\log \mu = 2.4758584$$
$$\log a^{\frac{3}{2}} = 1.0743556$$
$$\log \mu\, a^{\frac{3}{2}} = 3.5502140$$
$$\log k'' = 3.5500066$$
$$\log \sqrt{1+m_3} = 0.0002074$$
$$\log 1 + m_3 = 0.0004148$$
$$1 + m_3 = 1.0009554$$
$$m_3 = 0.0009554$$
$$= \frac{1}{1046.5}$$

For the ratio of the mass of Jupiter to that of the Earth, we have:

$$\frac{m_3}{m_2} = \frac{\frac{1}{1046.5}}{\frac{1}{331100}} = 316.4$$

(2).

Computation of the mass of Jupiter from the constant, $k = \frac{1}{15418000}$. We have from Young's Astronomy, page 391:

m_3 now varies as $g^1 r^2$. $\frac{m_3}{15418000} = g^1 r^2$. $g^1 = 2.647 \times 981 = 2596.07$ dynes.
$r = 43250$ miles $= 69604 \times 10^5$ centimeters.

$$\log r^2 = 19.6852698$$
$$\log g^1 = 3.4144229$$
$$\log 15418000 = 7.1884280$$
$$\log m_3 = 30.2877207$$
$$m_3 = 193960 \times 10^{25} \text{ grammes.}$$

For the ratio between m_1 and m_3, we have:—

$$\frac{m_3}{m_2} = \frac{193960 \times 10^{25}}{614 \times 10^{25}} = 315.9.$$

GENERAL NOTES.

In our last issue we completed the list of star charts arranged for each month of the year. They were taken from the Poole Brothers' Planisphere and make a complete guide for the study of the constellations.

We desire to secure twenty copies of the December number of *Astronomy and Astro-Physics*. We will pay forty cents each for them if returned to us in good condition during this month

We are exceedingly glad to begin in this number, a series of articles by Dr. T. J. J. See of the University of Chicago on the general theme of the study of Physical Astronomy, designed to furnish suggestions for Students and Amateurs. Nothing could be more timely and useful and we believe Dr. See is just the man for this important task.

Les Sciences Populaires.—"*L' Astronomie*" which has been published by C. Flammarion for the last thirteen years so successfully, has been abandoned, and Eugène Vimont, 15 Rue Lebrun, Paris, France, who was more or less interested in it has started a new monthly publication, *Les Sciences Populaires* which will treat of astronomy, meteorology and sciences of observation. The price of this new publication for all countries is 10 francs per annum. While we shall greatly miss the former by Flammarion, we hope the later publication by Vimont will be as good.

The Astro-Physical Journal, January, 1895 (Vol. I, No. 1) makes an excellent beginning. The two fine photogravure pictures of Mr. Barnard's work in photography with the Willard 6-inch lens on regions of the Milky Way, taken in 1892, are handsomely reproduced. They accompany an article by Mr. Barnard on Photographs of the Milky Way. The drawings of Mars made during the months of May and June, 1894, by Pietro Baracchi with the aid of the 4-foot reflector of Melbourne fill a full page photogravure plate. While the reproduction is very perfect, as we remember the copy, the details of the drawings were quite disappointing. The leading articles are as follows:

On the conditions which affect the spectrophotography of the Sun, A. A. Michelson. Photographs of the Milky Way, E. E. Barnard. The arc-spectra of the elements, Boron and Beryllium, H. A. Rowland and R. Tatnall. Attempts to photograph the solar corona without an eclipse, at Mount Etna Observatory, A. Riccò. Discovery of variable stars from their photographic spectra, E. C. Pickering. Preliminary table of solar spectrum wave lengths, H. A. Rowland.

Eclipses in March.—There will be a total eclipse of the Moon on the night of March 10, 1895, which will be visible throughout North and South America. The beginning will be visible in Asia, Europe and Africa and the ending in the Pacific Ocean.

ELEMENTS OF THE ECLIPSE.

Greenwich mean time of conjunction in right ascension, March 10, $15^h\ 31^m\ 25^s.6$.

Sun's right ascension $23^h\ 24^m\ 27^s.35$	Hourly motion $9^s.19$
Moon's right ascension $11^h\ 24^m\ 27^s.35$	Hourly motion $132^s.52$
Sun's declination 3° 50′ 3″.7 S.	Hourly motion 0′ 58″.8 N.
Moon's declination 3° 59′ 35″.3 N.	Hourly motion 17′ 54.3 S.
Sun's equa. hor. parallax 8″.6	Sun's true semi-diam. 16′ 5″.8
Moon's equa. hor. parallax 60′ 53.″2.	Moon's true semi-diam. 16′ 34″.7

TIMES OF THE PHASES.

	Greenwich Mean Time			Central Time.			
	d	h	m	d	h	m	
Moon enters penumbra	March 10	12	57.1	10	6	57.1	P. M.
Moon enters shadow		13	53.7		7	53.7	"
Total eclipse begins		14	51.5		8	51.5	"
Middle of the eclipse		15	39.3		9	39.3	"
Total eclipse ends		16	27.0		10	27.0	"
Moon leaves shadow		17	24.8		11	24.8	"
Moon leaves penumbra		18	21.2	11	12	21.2	A. M.

Magnitude of the eclipse = 1.627 (moon's diameter = 1)

A partial eclipse of the Sun will occur on the morning of March 26. It will be visible only in Greenland, the North Atlantic and Arctic Oceans and narrow strips of the bordering lands. The inhabitants of New Brunswick, Nova Scotia, and New Foundland may see a little of it just after sunrise. Observers in the British Isles will see the Moon just a little more than graze the edge of the Sun at about 10 o'clock in the morning.

ELEMENTS OF THE ECLIPSE.

Greenwich mean time of conjunction in right ascension, March 25, $23^h\ 36^m\ 49^s.8$ Greenwich meantime.

Sun and Moon's R. A. $0^h\ 20^m\ 26^s.22$	Hourly motion $9^s.09$ and $108^s.26$
Sun's declination 2° 12′ 46″.4 N.	Hourly motion 0′ 58″.9 N.
Moon's declination $3^h\ 37^m\ 43''\ 4$ N.	Hourly motion 14′ 39″.1 N.
Moon's equa. hor. parallax 8″.6	Sun's true semi diam. 16′ 1″.6
Moon's equa. hor. parallax 54′ 58″.4	Moon's true semi-diam. 14′ 58″.1

Magnitude of greatest eclipse = 0.353 (sun's diameter = 1).

The Transits of Mercury in 1661 and 1664.—A correspondent in the *Observatory* for November calls attention to the transit of Mercury of November 1664, and quotes a passage from "Evelyn's Diary" under date of October 24 (O. S.) where Mr. Boyle, Dr. Wallis and Dr. Christopher Wren were watching in an "inverted tube or telescope" for the transit of Mercury over the Sun's disc—but nothing happened "because the latitude was so great."

I happen to possess a copy of the ephemerides of "Vincent Wing, mathematician and Urania's servant," (less the title page) published in London 1656–1657, giving the eclipses of the Sun and Moon, the daily motions of the planets, etc., etc., for the years 1659–71 both inclusive.

Among these phenomena are the "Mercurial Eclipses" of April 23, 1661 (O. S.), and that of October 25, 1664 (O. S.)

I quote a few words about the latter transit because Wing predicts the transit for a later date than that on which the above observers were watching:

"Of the appearance of Mercury in the body of the Sun this present yeare. "Having diligently examined the Diurnall motions of the seven Planets, both in "longitude and latitude, upon the *Copernican Systeme* according to the rectified "Hypothesis of *Astronomia* Instauræta, and by observation of their harmonious "positions, I finde (amongst others) a very eminent Mercuriall Eclipse, ☿ being in "the lower part of his Orbe, or in that part of it next the Earth, shall therefore "be seen (by the help of a telescope) to passe between our sight and the Sun "(which will appear as a spot amongst his radiancy) which Phanomenon or ap- "pearance, because it may be richly worth my labor, and the Readers curious ob- "servation, I shall insert the calculation of it for the proof of its visibility."

Then follows his Calculation by which he predicts that the planet will transit the Sun 3′ 27″ south of the centre, at the following time:

The Centrall Ingresse	October 25*d.*	4Ho	28′	5″
Middle of the Eclipse		7	14	58
The Centrall Egresse		10	1	51

He adds that Eichstadius predicts:

"The conjunction at 3hs 31′ at London, so that Mercury will enter upon the "East limb of the Sun's Visible Disce about one a clock afternoon."

According to the prediction of Argolus, "this conjunction should happen on the 21 of October, at 10 A. M., but will not be central," etc.

Drake Observatory.—The telescope, donated to Drake University by General F. M. Drake, was mounted November 8, by Mr. W. R. Warner.

On the evening of the same day a brief dedicatory exercise was held in the University Place chapel, and was attended by about one thousand people.

Mr. Warner gave a twenty-five minute address on the telescope in general, closing with a description of the Drake telescope and a statement of the work it would do.

General Drake told the history of the purchase of the te'escope.

Professor Buck, of Iowa College, read a short paper in which he spoke of the outfit of a modern observatory, and of the work to be done in a college observatory.

Professor Weld, of the Iowa State University, gave a ten-minute talk, on the Value of Astronomical Research.

The courtesy of these two busy men from sister colleges, in leaving their work and coming to offer congratulations and to contribute to our dedicatory exercise, was greatly appreciated by myself and by Drake University.

Our local men also made short addresses, expressing interest in the event.

Letters were received from Professor Payne and Mr. Brashear, expressing regret at not being able to be present.

The occasion was regarded by the college as a red-letter day for the institution.

The telescope is an 8¼-inch refractor. The glass and other optical parts were made by Brashear, the objective being fashioned after the Hastings formula, and the mounting was done by Warner & Swasey, all of which insures a first-class instrument in every respect. Mr. Warner remarked that everything about the telescope was the newest and, therefore, the best that they have sent out from their shops.

The attachments to the instrument are a photographic lens, a micrometer and a helioscope.

The photographic lens is put in place by removing the outer disk of the visual objective and slipping the photo lens in its place. The mechanism is such that the exchange of discs is easily and quickly made.

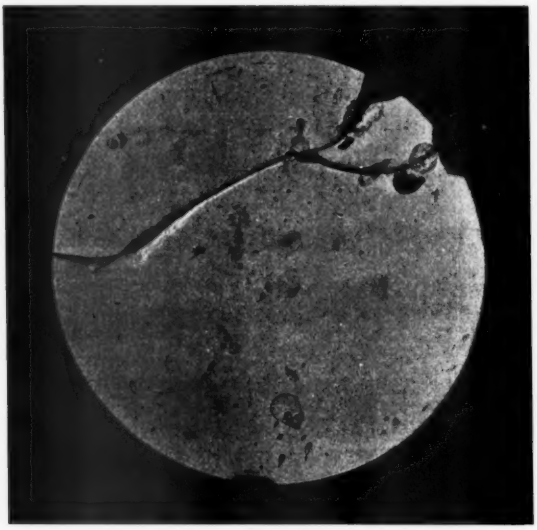
The telescope rests on a brick pier over sixty feet high, which is built in a tower of the college science hall. This height was necessary in order to get above the timber in which science hall stands.

The dome was built according to plans furnished by Warner & Swasey, who furnished also the iron running gear for it. The dome is easily handled. The cost was a little less than $1,000. The money for this part of the Observatory was contributed by citizens of Des Moines, mainly.

Almost every night since the instrument was mounted has been cloudy. Some glimpses, however, of Mars and Jupiter have been obtained, and indicate that the defining power of the glass is excellent.

The demand of the public to have a view through the telescope is almost clamorous. W. A. CRUSINBERRY.

Object-Glass Struck by Lightning.—By favor of J. A. Brashear, Allegheny, Pa., we have some interesting data concerning the breaking of an object-glass by a stroke of lightning. The accompanying cut is from a photograph of the objective after the event. The picture was purposely made dark to show plainly the spots that were left on it. This objective was made by Mr. Brashear for a transit instrument and was 2½ inches in diameter, the flint disc being placed outside according to his method. The objective was placed in an



aluminum cell, and all the marks except the very dark one near the shorter crack were made by particles of the fused aluminum imbedding themselves in the glass. In fact the glass and the metal seem to be thoroughly united, and it is perhaps one of the most interesting "freaks of nature" on record, especially in this line.

The instrument belonged to the United States Coast Survey and the incident occurred on Mt. Elbert in Colorado.

In connection with this incident Mr. Brashear says, in a private letter, "My friend, Professor Threlfall of the University of Sidney, writes me that aluminum can be made to adhere to glass tenaciously if the glass be held against a rotating aluminum wheel. I have not tried the experiment, but it would be interesting to do so in relation to the above phenomenon. The photograph was made by actual contact."

Naked-eye observations of Venus.—I have taken some pains during the present autumn to determine how long it would be possible to detect Venus with the naked eye, and the results of my observations may be of interest. My method of finding the planet has been to get it into the field of view of the 6-inch equatorial belonging to the Chamberlain Observatory, and then to glance along the tube which had now become a pointer indicating the direction in which to look for the planet. This method minimizes the difficulty of finding the object sought.

At 10 A. M. on Oct. 5th, I saw the planet distinctly with the naked eye. Professor H. A. Howe, the director of the Observatory, was with me, and saw the planet quite as plainly. On that day, the distance of the planet from the Sun was about 14.5 degrees, and its brightness as taken from the Nautical Almanac was 50.6.

At 9:45 A. M. on Oct. 30, I again saw Venus with the naked eye. I was alone when I made this observation. The planet's distance from the Sun was about 8 degrees, and its brightness, as taken from the Nautical Almanac, 48.6. It was quite a difficult object to distinguish with the naked eye, and required very persistent and careful looking to make it out at all. But as it was 1½ hours off the meridian, I don't doubt that it could have been seen when on the meridian for several days after the date mentioned. However, no good opportunity presented itself to me for looking for it again until Nov. 14, when it had approached to about 4 degrees from the Sun, and was no longer visible.

Turning to page 618 of ASTRONOMY AND ASTRO-PHYSICS for August, 1892, I read: "Mr. A. Cameron of Yarmouth, Nova Scotia, writes that he was able to see Venus with the naked eye *easy* at 12:30 P. M., July 6, three days before conjunction. The planet was only 6.5 degrees distant from the Sun." I cannot believe this record correct after what I have seen for myself, as the brightness of Venus July 6, 1892, was only about 10, whereas when I observed it its brightness was about 50. No persuasion is necessary to convince me that had Venus been only one-fifth as bright as she actually was when I observed her on Oct. 30, she would have been hopelessly invisible to me, yet she was 8 degrees from the Sun instead of 6.5. I put my observations on record as what can be seen by a person with normal eyesight in a very clear atmosphere at an altitude of 5,400 feet.

Denver, Colo., Nov. 14, 1894. ROGER SPRAGUE.

BOOK NOTICES.

A Few Chapters in Astronomy by Claudius Kennedy, M. A.

London: Messers Taylor & Francis, Red Lion Court. Fleet Street 1894, pp. 150.

The eight chapters of this small book have for their subjects respectively: On the visual illusions affecting certain Astronomical phenomena; The effect of the Earth's rotation on certain moving bodies; Deviation of certain projectiles from the rotation of the Earth; Foucault's pendulum; The position of the dynami-

cal high tide relatively to the celestial tide producing body; The horizontal pendulum; The Moon's variation and the Moon's parallactic singularity.

These are useful topics and are presented plainly and well, using in the main, only elementary mathematics in the discussions. An outline of the first topic will convey some idea of the author's plan and mode of treating them. It is as follows:

Difference between sphere of vision and plane of vision, middle of Moon's illuminated limb apparently pointing above Sun, deceptive appearance of Curvature of meteor paths, danger of making the radiant of a very sparse meteor system higher than the reality danger when using allignments only, of making the position of a very faint object lower than the reality, possible modification, by this illusion, of the apparent curvature of the very long tail of a comet.

The Planet Earth. An Astronomical Introduction to Geography. By Richard A. Gregory, F. R. A. S., Oxford University Extension Lecturer, etc. Messrs. Macmillan and Company, Publishers, 66 Fifth Avenue, New York, 1894, pp. 108. Price 60 cents.

As might be expected unusual attention is being given to the preparation of matter useful in University extension work, now so common everywhere. This little book is intended as a help in this direction. As the writer is scholarly and has experience as a lecturer, its matter and methods ought to be helpful in the field for which it is intended. One of the needs leading to its preparation is truly suggestive of its value. The way many elemental text books treat facts relating to the Earth's movements and its place in the Universe is very inadequate and sometimes scientifically wrong. The method of observation and induction should be used in Elementary Astronomy as in other physical sciences. Because this method has not been generally employed, elementary astronomy has not been retained in the American secondary schools nearly as generally as it doubtless otherwise would have been. Teachers who know anything about the branch do not need to be told that it is one of the most inspiring and useful branches that can be brought to the attention of young minds. This must be so from the subject matter it contains. The methods of teaching are however very defective and the suggestions of this little book in righting some things are very welcome. Though very simple and direct they are in the right direction for true interest and rapid progress in acquiring elemental ideas.

The five chapters in order have the following titles: The heavens we see, The Earth as a spinning globe, The size and mass of the Earth, Wandering stars, and The order of the Universe. Most of the illustrations are new and especially prepared for this book. As a whole it is commended to those interested in presenting its themes as teachers or lecturers.

Radiant Stars.—A Sequel to Sun, Moon and Stars. By Agnes Giberne. Preface by Mrs. Huggins and many illustrations. Publishers, Messrs. Macmillan & Co. 66 Fifth Avenue, New York, 1894. pp. 328. Price $1.75.

The era of popularizing science is fairly begun. There is no mistake about it. Current literature fully attests it. It is now too late in the day for the scientist to say that such a thing can not be done. He really means to say probably that some do not know how to do it. That is true and it is a pity.

Miss Geberne's book is opened with interest because we had read her book entitled the "Sun, Moon and Stars," published by The American Tract Society of New York in 1892. This is a book of about the same size and is intended as a sequel to the former one. Its three divisions are, Astronomy, old and new, the spectroscope and its teaching and the stellar universe. We have read it through with care to see how the author would popularize such topics as the nature of light, the nature sight, the dark lines in the spectrum, the make-up of the sunbeam, the photography of the stars, the shrinking of the Sun and a score of others that are themes for chapters. To say that the author has done her work *well* is not enough. By apt illustration, plain language and lively imagination, we have a rendering of these themes, in a way to delight any reader who has interest in such scientific themes. The book is a good one for the general library not only because of its style of composition but also because its ideas and facts are modern and therefore very largely useful. Such books are infinitely better for young people than very much of the current literature of the day.